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New England Water Works Association.

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THE SHIPPING SITUATION AND THE CONSTRUCTION OF THE SQUANTUM DESTROYER PLANT.

BY THOMAS C. ATWOOD, RESIDENT SUPERVISING ENGINEER.

[*September 11, 1918.*]

At the beginning of the war with Germany the Government was confronted with many problems, not the least of which was the problem regarding shipping. As is generally known, the most serious threat against the successful prosecution of the war, and especially to our own participation, was the unrestricted use of submarines by Germany. This action by the enemy not only threatened to destroy the transports, preventing us from sending an adequate army to Europe, but also to prevent us from supplying our own troops and those of the Allies.

The only really effective means of combating the submarine has been found to be warships of a type known as " torpedo boat destroyers," and the first action of the Navy Department was to call for the rapid construction of a large number of these. Other boats were pressed into service, of course, and a smaller class, which could be built more rapidly, namely the 110-ft. submarine boat chasers, were also contracted for; but these were of little assistance in convoying troops and supplies across the ocean, for which purpose the destroyers were absolutely essential.

The 110-ft. boats were very useful in Europe, so long as submarines operated within about one hundred miles of shore, but the submarines soon began to carry their operations far beyond this limit, and destroyers were necessary for offensive operation

against them, wherever they might be found, although an intermediate class was designed for special service in this particular respect. This was the 200-ft. class, known as the "Eagles." None of these, however, have as yet been put into service.

Destroyers, then, were the one thing that we needed, and needed in large numbers, not only to wage offensive war on the submarines, but to convoy our ships across the ocean, both the transports and the supply ships. The convoy system was soon developed to protect merchant ships, as well, and so effective has this system become that losses were cut down from nearly ten per cent. to about one per cent.

When we entered the war the number of destroyers in the English, French, and Italian navies was considerable, but they were devoted almost entirely to convoying troops and protecting the main fleets against submarine attacks. Merchant ships had to get along the best they could. On the most important station which the British had for protecting commerce there were only seven destroyers, and it went without saying that these boats could not be used to convoy ships, as they had to remain on the station to chase down every submarine which was reported.

It may be well to give a brief summary of the general shipping situation. In 1914 there were something like 53 000 000 tons of shipping, — including the Great Lakes and the coastal shipping and everything, — and of that amount about 18 000 000 tons have been destroyed by the submarines and about 5 000 000 more of German shipping were interned, so that only about 30 000 000 tons remain of the original amount. To this must be added the 10 000 000 tons which have been built during the war, a much smaller amount than usual, of course, because the British construction was very largely cut off when the war started. It is only within the last year that the British have started their shipyards going again on merchant shipping, and they are now approaching their normal yearly output. There is now possibly 40 000 000 tons available. If the war had not occurred and normal building had proceeded, there would have been about 65 000 000 tons available now; so it is easy to see how serious the shortage is. The needs of the governments are so large that a very small amount remains available for private use.

The situation has been met in this country in two ways: First, by the building of destroyers to protect what shipping we had left; and, second, by building additional shipping as rapidly as possible. The destruction program of the Germans, beginning with February, 1917, called for the destruction of about a million gross tons of shipping per month, and they actually approached this at first; but now the destruction has been reduced, in August, 1918, to around 250 000 tons per month; and during this present summer the shipbuilding has increased so that we have passed the destruction limit and are actually building more ships than are being sunk every month by the submarines. We have just passed the low point and are starting on the upward curve however, so it is going to be months and years before we catch up to where the shipping should be.

It is pleasing to note that the submarines have also been destroyed. The best information I have been able to secure is that about 250 or, possibly, 300 submarines have been built by Germany, and of these probably 150 have been destroyed, leaving 100, or possibly 150, still operating, and of these not more than one third are at sea at one time.

The convoy system has greatly helped in the matter of preventing submarine losses of shipping, because the ships go under the convoy of destroyers, and it is an extremely risky matter for a submarine to show itself anywhere near a destroyer, for if a destroyer does not get it with its guns it is very likely to with the depth bombs.

Of course the wastage of shipping has not been entirely due to the submarines, but it has been due also to navigation losses, which are much greater now on account of war conditions, so many lighthouses and lightships being out of commission, and ships running without lights and without fog-horns are very likely to collide, or much more likely than in ordinary times.

The shipbuilding program in this country has been carried forward very rapidly both by the Navy Department and by the Shipping Board, and while the old yards — the ones which were in the service at the beginning of the war — have been almost entirely occupied with the Navy work, a great many new yards have been built by the Shipping Board; so that now that Board has

159 yards in operation, with some 750 ways. About half of the yards build steel ships and the other half build wood, composite, and concrete ships. That the production is increasing very rapidly is evidenced by the fact that this summer the number of rivets driven, which is the index to the amount of steel tonnage being turned out, has increased about 100 000 rivets each month, it having been 400 000 rivets in April and now being double that number.

The Navy Department confined its program almost entirely to destroyers at first, but within the last two or three months orders have been given to go ahead with the capital ships, which shows that the submarine situation is well in hand, or else every effort would still be devoted to building destroyers.

The shipbuilding situation is probably more responsible for the shortage of labor in this country than any other industry. When one realizes that before the war we were only turning out about 250 000 tons of shipping per annum, while now we are aiming at 10 000 000 tons per annum and will actually run up next year, probably, to 6 000 000, one can see what a tremendous overturn there has been in the business. The number of people engaged in shipbuilding before the war was not over 50 000, while now there are nearly 1 000 000 people, if we include both the Shipping Board and the Navy Department. The Navy Department has had about as much work on hand as the Shipping Board, until recently. This has created a labor situation which is unique in the history of this country because so many different men are engaged in shipbuilding who never were engaged in that class of work before.

This is the reason why shipping has not increased at a greater rate. In another year, when these men have been trained to be mechanics, there is going to be a very great increase in the amount of shipping put out, because shipbuilding methods have been improved so greatly and the number of types and sizes of ships reduced to such an extent that a man should turn out more tons per annum than formerly. Before the war it was a very good yard which would turn out 20 tons per annum per man of merchant shipping, and that is cut down now by inefficiency in such yards to about 15 tons, and in some even less. But there are

yards in the country which are turning out as high as 35 tons, and the reason is found in the fact that these yards are ones which got started early and corraled all the good mechanics there were and would not let go of them, and the others had to take what was left.

The shipbuilding facilities of the country were found inadequate to produce the number of destroyers needed within the time required, so extensions to existing yards were made and in addition the large plant at Squantum was projected, this being built as a strictly Navy plant, designed entirely for the construction of destroyers and boats of similar size. The plant cannot be used for the building of larger ships without the construction of extensive additions, because the buildings and machinery are planned for destroyers, and the ways are not heavy enough for larger craft.

Everything is laid out in this plant for the most rapid construction possible. Before the war it was customary to take from eighteen to twenty-four months to turn out a destroyer, but under the pressure of war conditions this time has been reduced at old plants to five or six months, and it is hoped at the Squantum plant that this time will be reduced even more.

One destroyer has been launched in fourteen days from the time of laying the keel; but this is what might be called a "freak performance." Every piece of steel which was required in that boat — and there are some 24 000 different pieces — was ready to put into place before the keel was laid; months had been spent in getting it ready. This "stunt" was pulled off at the Mare Island Navy Yard, California.

In a plant like that of Squantum, however, turning out destroyers in regular succession, it should be possible to build a boat, ready for launching, in about two and one-half months, and to outfit her in about two months more, making the minimum time for average construction four and one-half months. This, however, can only be attained by an efficient organization working at top speed.

The present contract calls for 35 vessels to be built at Squantum, all within twenty-one months from the time the work on the yard itself was started; and this, it will be seen, is much less time than it formerly took to build one destroyer in an established yard.

The construction of the Squantum Destroyer Plant was begun on October 6, 1917, and was carried on, day and night, throughout the following winter, which all remember as being the most severe on record. A working force of about 6 000 men was employed, and the construction plant was much larger than usual in order to procure the rapidity of work and comfortable conditions for the workmen.

The design of the plant was carried on at the same time as the construction, and the engineers succeeded in keeping ahead of the work in almost all instances, there being no delay of any consequence. They had had a short time, perhaps a month before the contract was awarded, in which to prepare for the construction work, but only general decisions could be made in this time, so that practically all the detail work had to be done during the construction period.

The plant occupies a tract of some 700 acres, facing Dorchester Bay in Boston Harbor, on the Neponset River, and lying entirely within the city of Quincy. The plant proper occupies an area of about 90 acres, directly on Dorchester Bay, part of this area being above tide level and part of it being salt marsh with from 5 to 15 ft. of mud overlying the solid clay beneath. A channel giving 12 ft. of water at mean low tide was dredged from the main Dorchester Bay channel into the plant, and a large launching basin dredged out to provide for handling the boats when launching and outfitting. This dredging was done by hydraulic dredges which discharged the excavated material on to the marsh and made ground on which to build a large part of the plant.

The foundations for the buildings consisted of spread footings where solid ground was available, and concrete piles elsewhere, except that foundations of the wharves were all constructed of oak piles.

The buildings proper were divided into two classes, both being permanent construction. The high buildings, all of which contained traveling cranes, were of steel frame construction, glass sides and wooden roofs, the latter being mainly of sawtooth construction. The low buildings, and also the main office building, were of mill construction.

LAUNCHING FIRST DESTROYER, JUNE 18, 1918.

ICE CONDITIONS DURING CONSTRUCTION OF WHARF.

The buildings are thoroughly sprinklered; the wet system being used in heated buildings and the dry system in unheated buildings.

This plant is unique, in that the ships are built entirely within the new buildings, both before launching and afterwards. By this means, it is expected that at least two months will be saved in the building of the destroyers under the present contract, and the cost of the roofs — perhaps $2 000 000 — is so much less than the possible saving, due to earlier construction of the destroyers, that it becomes an economical proposition to completely enclose the building ways and the outfitting basin.

The plant is laid out for the most economical construction possible of the destroyers, and is thoroughly equipped with every possible labor-saving device. All steel is taken out of the railroad cars by overhead cranes and stacked in numbered racks, so that each individual piece is immediately available, and, when needed, is taken on cars into the adjacent fabricating shop, where it is worked into final shape and carried into the next building to be assembled into bulkheads, or placed directly on the boats.

Overhead cranes carry the fabricated steel from the assembly building directly to the boats, each boat being served by two 3-ton cranes, one of which can drop steel directly over the center line of the boat.

The lighting of the buildings is so good that no artificial light is needed, but thorough light is provided for working at night.

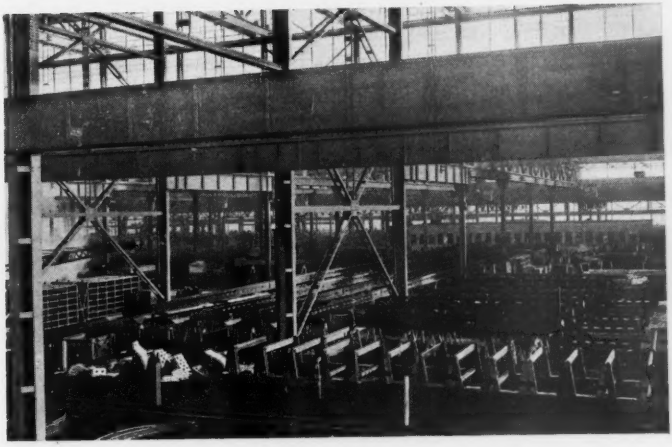
Compressed air and electrical power is distributed to all parts of the buildings from the main power house, where current is received from the Boston Edison Company, and transformed or converted into the various forms necessary. Directly connected compressors supply the compressed air needed.

A complete galvanizing shop, for galvanizing material up to plates 30 ft. long by 5 ft. wide, is adjacent to the assembly shop.

A large machine shop provides means for doing all machine work on the ships, which it is advisable should be done at the plant.

One of the most important outfitting shops is the pipe shop, in which is done all the copper, brass, and iron piping work, of which there is a vast amount on each destroyer.

INTERIOR OF WET SLIPS.
(Fitting-out Basin.)



INTERIOR OF ASSEMBLY BUILDING.

The turbines driving the destroyers have a total horse-power of about 28 000, so that it may readily be seen that the piping required between the boilers, turbines, compressors, and all the auxiliary machinery is very large, and all has to be specially made up in order to fit in the required space available.

Another large shop is the sheet-metal shop, where all the light metal work is done; the shop being equipped to handle steel plate work up to $\frac{5}{16}$ in. in thickness. Here the up-takes, smoke stacks, etc., are made, as well as innumerable metal interior fittings.

Additional shops are provided for the riggers, outside mechanics, carpenters, electricians, and the yard maintenance force.

Storage for the necessary materials other than the heavier parts is provided in the storehouse, and storage for the heavier material which comes in ready for placing in the ships is provided in the warehouse. Here, such equipment as pumps, blowers, etc., is kept until time for installation.

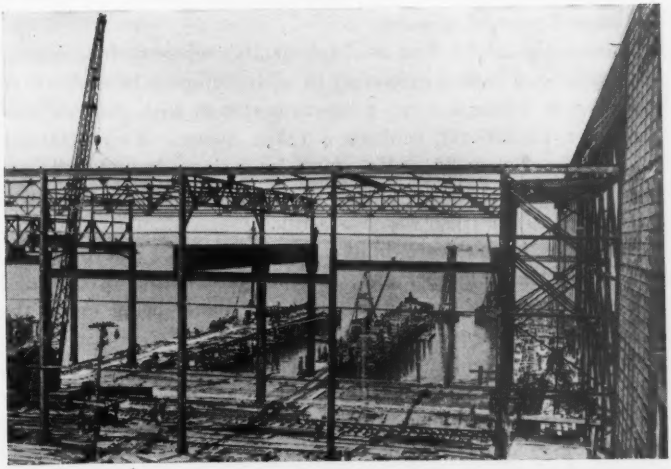
The yard is served by railroad connection from the New York, New Haven & Hartford Railroad, — Old Colony Division, — and a complete system of tracks allows the material to be taken to any part of the yard or buildings.

Locomotive cranes are provided for handling material which is desired to be stored in the open in various parts of the yard, and for handling coal and similar materials.

A system of macadam roads was built to give access to all the buildings, and the remainder of the ground is graded to provide for the greatest usefulness of the space available. As a large part of the area was filled in by the hydraulic dredge with material from the launching and outfitting basins, and as this material consisted mostly of clay, it was necessary to place 12 to 18 in. of dry, sandy gravel over the top of the hydraulic fill in order to make it possible to use the surface. This material was obtained from gravel pits in Wollaston and East Weymouth.

The plant proper is completely fenced in, with lights provided to make guarding easy, and at the gates are special houses built for checking employees in and out, and a service building containing a well equipped hospital and employment office.

A restaurant, with a seating capacity of 1 500, is provided for use of the employees, and the bunk-houses, built for construction



CONSTRUCTION OF WET SLIPS.

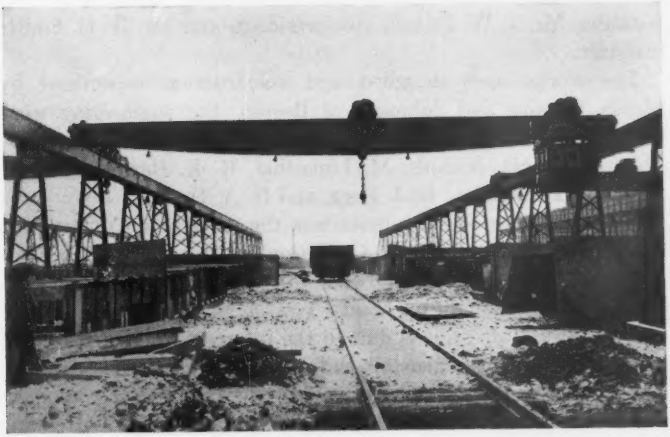


PLATE STORAGE YARD.

work, have been left for use in housing employees of the plant if this should prove necessary.

The yard is served from the Metropolitan water system, a complete system of piping extending to all buildings. In addition to this there is a complete fire protection system with pressure supplies by a 100 000-gal. tank on a 125-ft. tower. Two 1 000-gal. fire pumps, electrically driven, for taking water from Dorchester Bay, are provided for use in case of a large fire, but the system is maintained full of fresh water as a rule.

Accessory plants were built at Buffalo, N. Y., Providence, R. I., and Cambridge, Mass., for the construction of turbines, boilers, and pumps, respectively, all the plants being under the same general appropriation and management.

The plant was built under the supervision of the Navy Department, Admiral H. H. Rousseau in charge of new plant construction under the Bureau of Yards and Docks, and the field construction in charge of the speaker, as supervising engineer, assisted by Mr. C. L. Hammond and Mr. F. I. Winslow. The auditing was in charge of Paymaster Alvin Hovey-King, U.S.N., with Assistant Paymaster C. L. Bates, U.S.N., in direct charge.

The plant was laid out by the Bethlehem Shipbuilding Corporation, Mr. J. W. Powell, vice-president, and Mr. H. G. Smith, manager.

The works were designed and construction supervised by Messrs. Monks and Johnson, of Boston, the engineering work being in direct charge of Mr. Johnson of this firm, assisted by Messrs. John R. Nichols, M. Linenthal, R. R. Burnham, H. O. Jackson, L. I. Killian, R. J. Fogg, and H. A. Hoyt.

The contractor for all plants was the Aberthaw Construction Company, of Boston, Mr. L. C. Wason president, Mr. J. A. Garrod general superintendent, and Mr. W. H. Ryerson superintendent on the Squantum plant.

A great deal of credit is due all the interests concerned for the hearty coöperation which all endeavored to give, to secure the best and most rapid results possible.

The completion of this large plant within the time allotted and the severe weather encountered reflects great credit upon the entire construction force.

The work was far enough along so that active work on building destroyers began January 1, 1918, and the plant substantially completed before June 1, 1918. The keels of the first five destroyers were laid April 20, 1918, and the first boat launched July 18, 1918.

THE MEASUREMENT OF RAINFALL AND SNOW.

BY ROBERT E. HORTON, CONSULTING ENGINEER, ALBANY, N. Y.

Introduction.

In this paper the word "rainfall" will sometimes be used to describe all those forms of atmospheric precipitation which are ordinarily measured and included in rainfall records, and which consist mainly of rainfall and snow. Other forms of precipitation, including dew, frost, and mist, — which for the most part are not ordinarily included in rainfall records, — will not be discussed.

Probably almost every one who has kept or used rainfall records has had some question lurking in his mind at times as to the accuracy of such records. Again, the question often arises as to whether a rainfall record taken at one location will furnish a reliable indication, either of the mean, the annual, or the rainfall in individual storms at near-by locations, or over any considerable area surrounding the rain gage.

The object of this paper is to describe methods of measuring of rainfall and snow, and to discuss the errors and accuracy of such measurements, with a view to suggesting methods of securing rainfall records having the highest possible degree of accuracy and usefulness.

Some attention will be given to the question of the reliability of the results obtained from a single rain gage as applied to larger or smaller areas around it. This ever-recurring question is of special importance in connection with gravity water-supply systems dependent upon small drainage areas, since it does not often happen that there is more than one rain gage located within or closely adjacent to a water-works catchment basin of, say, ten square miles area or less.

Neither the causes of rainfall, its characteristics or variations, nor methods of analysis and use of rainfall records, is here considered. It is conceived that a discussion of these subjects might

form the basis of a far more interesting paper than can be evolved from the relatively dry details of the technique of rainfall measurement. Inasmuch, however, as there are numerous rainfall records maintained in conjunction with water-works systems, — especially throughout New England, — and the results seem to justify a general increase in the maintenance of such records by water-works engineers, officials, superintendents, and reservoir keepers, it seems worth while to devote some attention to the subject of the best methods of locating rain gages and of keeping records of rainfall and snow.

As a foundation for this discussion and as affording added interest to the subject, the development of the rain gage and the methods and extent of rainfall observations in various countries are briefly treated.

Early Rain Gages and Rainfall Records.

Geologic considerations indicate the occurrence of rain back to the dawn of stratigraphic history. Direct evidence of the nature and occurrence of rain in early geologic times is found in rain prints on rocks. Such records, showing the actual impressions made by raindrops on soft beds of clay, are found in the carboniferous rock in England and in the still earlier rocks in Glacier National Park in the United States. Such rain prints probably represent light showers which occurred during low tide, the soft mud in which the imprints were formed being covered with sediment immediately after the rain and so preserved.

As regards written records, it seems there must have been some sort of a rain gage in use in India as early as the fourth century B.C. In a book, "Arthastra," or the Science of Politics, by Chanakya, the famous minister of Chandragupta, the founder of the Maurya dynasty in India, and the grandfather of Asoka, there are certain statements from which we are led to believe that the Indians of the fourth century B.C. had a good idea of meteorology. In the chapter on the " Superintendent of Agriculture " is found the following:

" The quantity of rain that falls in the country of Jangala is 16 dronas; half as much more in Anupanam countries; $13\frac{1}{2}$ dronas

in the country of Asmakas; 23 dronas in Avanti, and an immense quantity in Apparantam; the borders of the Himalayas, and the countries where water-channels are made use of in agriculture." *

In the Mashnah, a collection of religious writings of the first century, there have been found recorded measures of rainfall in Palestine during the first century of our era. These are probably the first quantitative observations of precipitation now in existence. Hildebrandsson states that these observations agree as to quantity of rainfall with modern pluviometric records at Jerusalem. (M. W. R., June, 1916, p. 345.)

So far as rain gages of modern types are concerned, it is known that they have been used since the days of Leonardo da Vinci, 1452–1519.

The invention of the rain gage is, however, often attributed to an Italian, Benedetto Castelli, who, in June, 1639, informed Galileo that he had measured the rainfall with a "vase one spanne in depth and half a spanne in diameter." Its invention is also sometimes credited to Sir Christopher Wren, in 1663. Wren also devised a recording rain gage in 1670.

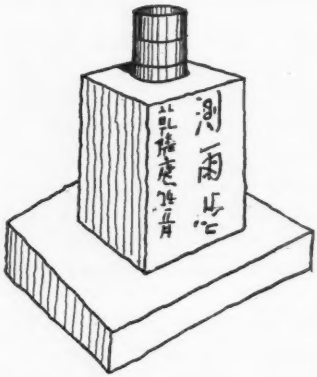


FIG. 1. THE OLDEST RAIN GAGE. ERECTED AT TAIKU, 1770.

Dr. Y. Wada, director of the Korean Meteorological Observatory, has shown that rain gages were in use in Korea as early as 1442. The dimensions of the ancient gage were: depth, 30 centimeters; diameter, 14 centimeters. A gage of the period of 1770 was found by Wada on an inspection trip actually in use at the observatory of Chemulpo, Korea. On the granite pillar of the gage represented in the illustration (Fig. 1), found at Taiku, are engraved three large Chinese characters meaning "Instrument to measure rain," and seven

* Jogindra Nath Sammadar, Hararibagh, Bengal. *Quar. Journ. Roy. Met. Soc.*, January, 1912, pp. 65–66.

smaller characters meaning "Constructed in the fifth month of the cycle of the year," a date in the Chinese calendar corresponding to 1770. This is evidence that rain observations began in Korea two centuries before they were made in Europe, and, what is more remarkable, there appears to have been an udometric survey, or network of rain-reporting stations. The reports were probably used in connection with the rice crop.

A conical rain gage intended to multiply the depth of precipitation so that it could be measured accurately was invented and used by the physicians Kanold and Kindmann, of Breslau, between 1717 and 1727.

A conical rain gage was introduced in the United States of America by Simeon DeWitt, of Albany, in 1807, and described in a paper before the Albany Institute.*

The earliest modern rainfall records were instituted at Paris in 1668. The longest continuous record is that kept at Padua, begun in 1725 and still continued.

Probably the earliest long record kept in the United States was that of Professor Winthrop, at Cambridge, Mass., which was begun in August, 1749, and continued until the day of the battle of Lexington, 1775. This record is given by Goodnough.†

A record at New Bedford, Mass., was begun by Samuel Rodman in 1814 and was continued down to 1898, covering one hundred and thirteen years.‡

DATE OF BEGINNING OF EARLY PRECIPITATION RECORDS.

Location.	Date.
Paris, France	1668
Townley, England	1667
Ulm, Germany	1715
Padua, Italy	1725
Milan, Italy	1764
New Hartford, Conn	1804
New Bedford, Mass	1814
Boston, Mass	1818
Albany, Troy, Utica, N. Y	1826

Most of these records have been kept continuously to the present time.

* See *American Journal of Science and Art*, Vol. 22, pp. 321–4.
† JOURN. N. E. W. W. Assoc., September, 1915, p. 332.
‡ JOURN. N. E. W. W. Assoc., September, 1915, p. 365–7.

Distribution of Rainfall Records.

Rainfall gaging stations are generally distributed over the British Isles, United States, Southern Canada, Germany, Austria, France, Japan, Italy, India, Australia, Java, and Argentina, and to some extent in China, Mexico, Russia, and the Philippines, South Africa, and Denmark.

Dr. Buchan (Vol. 3, Meteorology, Bartholomew, Physical Atlas, London, 1899) states that there are 30 000 stations for observing rainfall, scattered over the continents and islands of the globe. There is one station or more to every 40 square miles in Jamaica, Barbados, St. Kitts, Great Britain and Ireland, Denmark, Saxony and the Straits Settlements, Victoria and Mauritius. For Europe, United States, India, and Australia, the general average is about one station for every 2 000 square miles. In the thickly settled portions of the United States there is about one station to 500 square miles, the usual practice in the eastern United States being the maintenance of one station in each county. In sparsely settled regions in western United States there may be only a single station in an area of 16 000 square miles.

There are about 2 000 rainfall records in the United States having a duration of twenty-five years or more, and probably an equal number of shorter records of ten to twenty-five years' duration. At the present time there are about 200 regular United States Weather Bureau stations equipped with recording instruments. There are 3 000 stations, the pluviometric results for which are regularly reported in the publications of the United States Weather Bureau. France has 2 000 stations, and England about 5 000.

Numerous rainfall records were established in the period 1825 to 1850 at the academies in the state of New York. The earlier records in the western states were often kept at forts and barracks.

Various Forms of Rain Gages.

The earliest rain gages were mere prismatic containers, the depth of catch being measured directly. So far as I can learn, the Simeon DeWitt or Albany gage (Fig. 2) was the first having a

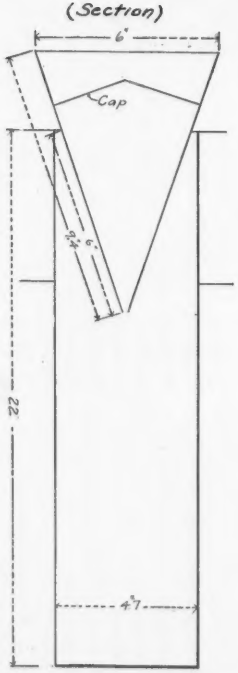


FIG. 2. DEWITT RAIN GAGE.

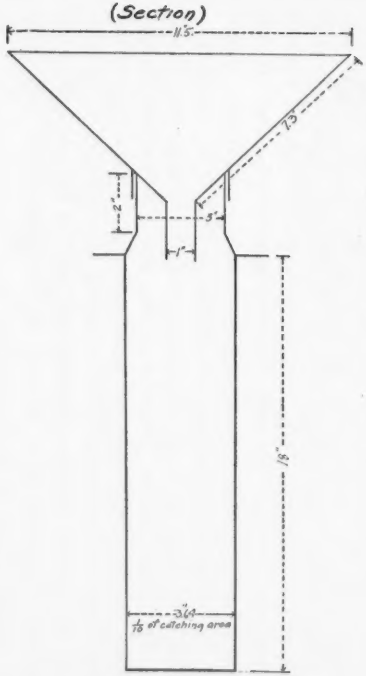


FIG. 3. SMITHSONIAN RAIN GAGE.

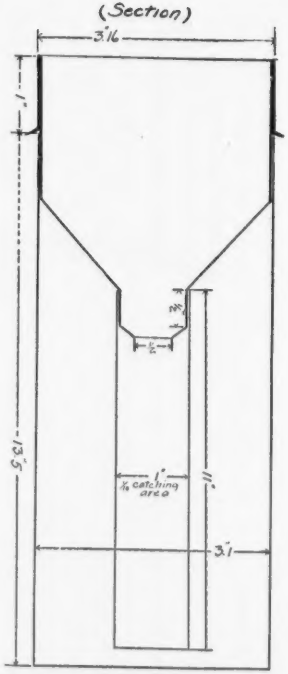


FIG. 4. FUERTES GAGE.

funnel with a small orifice intended to reduce evaporation loss. This seems also to have been one of the earliest gages in which the depth of rainfall was multiplied by catching and measuring it in a receiver, smaller in diameter than the funnel of the gage, thus facilitating accuracy of measurement. These two points represent practically the only significant improvement in modern rain gages over the most primitive prismatic types. There is no reason to doubt that so far as the actual catch is concerned the Korean gage (Fig. 1) is as accurate as the best modern gage. The errors and uncertainties of such gages result from evaporation loss and inaccurate measurement of the catch.

In the earlier days, many special types of rain-gage funnels were devised, such as the inverted cone of the DeWitt and Smithsonian gages, and the splayed rim surrounding the funnel of the Von Bezold gage. Fortunately, as will be shown later, these devices do not seem to have materially reduced the accuracy of the records obtained. Such devices have, however, mostly fallen into disuse, and cylindrical gages are now in general use the world over. Some of the earlier type of gages are shown in Figs. 2 to 5 inclusive. Figs. 6 to 10 inclusive show the principal forms of gages now in use in the United States, England, India, and Continental Europe. They are practically identical in the principles of their construction, but vary in size, methods of setting, and methods of measuring the rainfall caught. The names, sizes of funnels, and usual heights of funnels above ground, of the principal rain gages now in use, are shown in the following table.

CHARACTERISTICS OF VARIOUS RAIN GAGES.

Name.	Used in	Diameter, In.	Usual Height.
Meteorological Office.....	England	8	
Snowdon.....	England	5	1 ft.
Symons.....	India	5	1 ft.
Hellman.....	Prussia		1 meter
Simeon DeWitt.....	Early U. S. A.	6.00	8 ft.
Smithsonian.....	Early U. S. A.	11.50	Flush
Fuertes.....	Old N. Y. State	3.16	
U. S. Weather Bureau.....	U. S. A.	8.00	4.5 ft.
Friez recording.....	U. S. A.	10.50	
Glaisher.....	England	8.00	

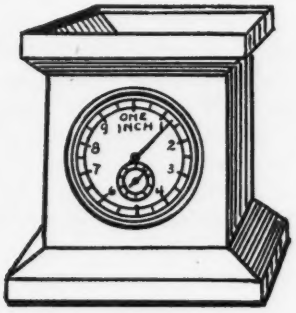


FIG. 5. "WILSON" SELF-REGISTERING RAIN GAGE.

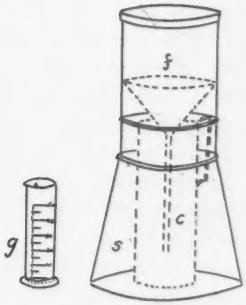


FIG. 6. RAIN GAGE, SNOWDON PATTERN, WITH SPLAYED BASE, BRITISH METEOROLOGICAL OFFICE PATTERN.

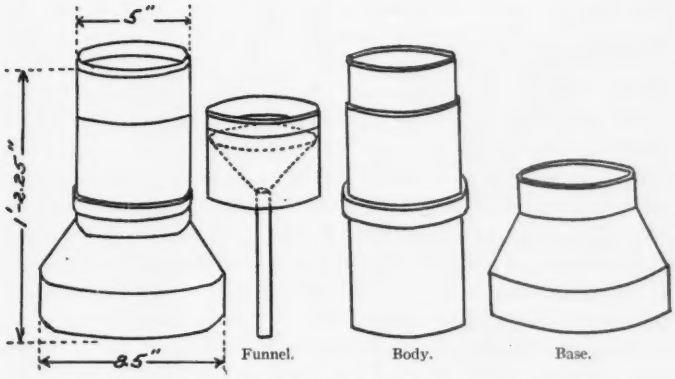


FIG. 7. SYMONS RAIN GAGE, INDIA TYPE.

With the English types of gages, including the Symons, Snowdon and Meteorological Office gages, a graduated measuring glass is used; with the Glaisher and Hellman gages the rain is caught in a metallic receptacle and afterward poured into the measuring glass. The Glashier gage (Fig. 8) has an inverted siphon outlet funnel affording a water seal intended to prevent evaporation.

The Casella gage has a special insulated outer jacket which will prevent freezing of the water in the gage in ordinary winter weather. Inasmuch as leakage of the overflow can of gages of the U. S. Weather Bureau type, resulting from freezing, is a not uncommon occurrence, the use of the insulating jacket seems to merit consideration.

Gages with square funnels have occasionally been used, such, for example, as the Wilson gage (Fig. 5) an English instrument having a dial and hands, by which the amount of rain caught is indicated directly in inches and hundredths.

United States Weather Bureau Rain Gage.

The accompanying Fig. 10 shows the form of non-recording rain gage in common use in the United States. The diameter of the gage funnel, *A*, is 8 in.; the diameter of the inner tube, *C*, is such that, allowance being made for the measuring stick (not shown) the area of cross-section of the tube equals 0.1 the area of the mouth of the funnel, so that the depth of rainfall is multiplied ten times. A cedar measuring stick about $\frac{3}{32}$ in. thick by $\frac{1}{2}$ in. wide is used. This is graduated in inches and tenths, in such a manner that an actual depth of 1 in. in the inner or reservoir tube of the rain gage reads 0.1 in. on the stick. The depth of moistening of the portion of the cedar rod inserted in the water in the inner tube shows clearly after the rod is withdrawn for the purpose of taking the reading.

There is no standard or uniform height above ground at which rain gages are placed in the United States. As a rule, the nearer the ground the more accurate is the record obtained by a rain gage. Inasmuch, however, as the gage should be high enough to prevent interference by children and animals, a height of the top of the funnel of 4.5 ft. is found convenient.

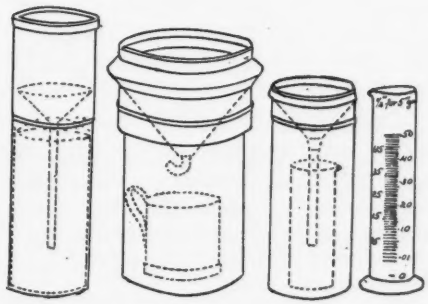


FIG. 8. BRITISH RAIN GAGES.

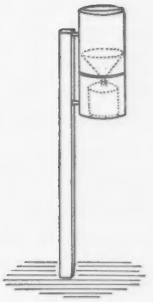


FIG. 9. HELLMAN RAIN GAGE.

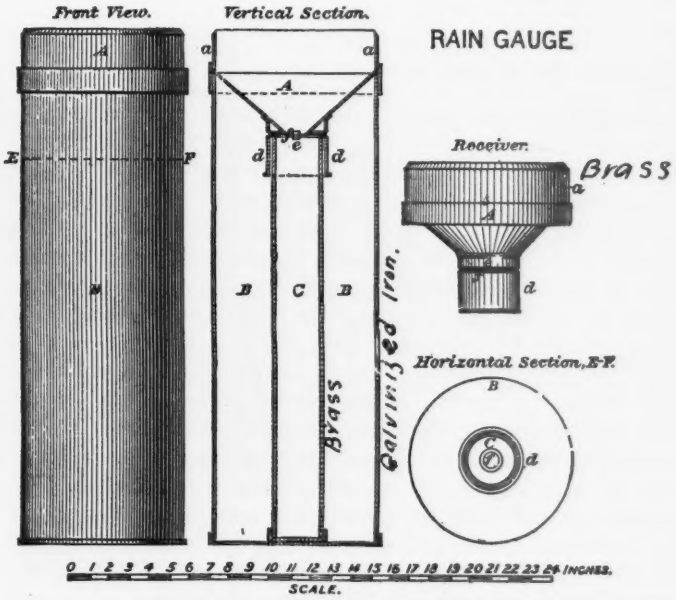


FIG. 10. U. S. WEATHER BUREAU RAIN GAGE.

In the winter time the funnel *A* and the measuring tube *C* are removed, and only the overflow can *B* is left in position. One method of measuring snow caught in the overflow can is to melt the snow, pour the water into the brass measuring tube, and measure it in the usual way with the cedar stick.

"The method just described is objectionable, owing to the time required and to the loss of the snow or water by evaporation. The following plan is much better: Take the overflow into a room and pour it into one measuring tube full of water to the brim, preferably warm. In cases of deep snowfall more water will be required. This will melt, or at least reduce to a fluid slush, a considerable amount of snow. The measuring tube should then be filled to the brim from the melted contents of the overflow and emptied; thereby discarding a quantity of water equal to that added. The remaining water in the overflow when measured in the tube then gives the actual depth of melted snow." (Circular E, U. S. W. B.)

Mountain and Tropical Gages.

In regions having excessive rainfall it is necessary to provide rain gages capable of retaining a much larger amount of precipitation than can be stored in the ordinary type of gage. Special deep gages, sometimes called "mountain gages," are available for this purpose, and the English mountain gage of Negretti and Zambra will hold 27 in. of rain. In mountain regions where regular observers cannot be obtained, and gages can only be occasionally visited, good records of the total monthly precipitation can be obtained by the use of such gages, where otherwise data would be wholly wanting. Special attention is directed to this gage in this connection, as water-works engineers often desire numerous records of rainfall in connection with their reservoir systems but are hampered in procuring them for want of observers.

It is suggested that one or two ordinary gages, read daily, in conjunction with several gages of the mountain type read weekly or monthly, will oftentimes prove a valuable combination. One of the difficulties of the use of gages read occasionally is the avoidance of loss of rain caught by subsequent evaporation.

It is suggested by J. C. Alter (*Monthly Weather Review*, Novem-

ber, 1907, p. 511) that by placing 0.2 in. of pure olive oil on 0.2 in. of water in a regulation Weather Bureau pattern 8-in. rain gage, with the funnel receiver, but without inner tube, and exposing the gage in the ordinary manner, the rainfall for a considerable period may be caught and retained with but little loss by evaporation. Experiments by Hall, using such a gage in parallel with a Weather Bureau tipping-bucket gage, showed a deficiency of three per cent. for the gage containing olive oil for the period April 16 to November 3, 1907, with a total rainfall of 7.77 in. Hall found that in light showers the fine drops did not penetrate the olive oil but remained supported on it and were lost by evaporation.

Recording Rain Gages.

The type of recording rain gage in most general use in the United States is the Friez tipping-bucket gage, Fig. 11. This has a funnel 10.5 in. in diameter, and, like the Weather Bureau gage, it has a brass measuring tube having an area one tenth the funnel area. The tipping bucket has two compartments, each holding .01 in. depth of rain. The weight of this rain tips the bucket, forming a contact and closing an electrical circuit, by which the exact time of each tipping of the bucket is recorded on the drum of a chronograph. This is a very satisfactory instrument in most respects. Obviously, one compartment of the bucket may remain partially filled when the rain ceases, and if this water does not evaporate the bucket will tip before .01 in. is fallen in the next subsequent rain. In very light showers this throws some error into the record as regards distribution of the rain, and makes it impossible to determine the rainfall duration with precision ex-

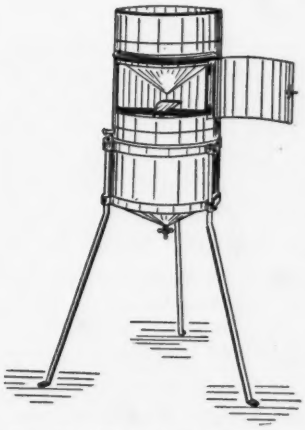


FIG. 11. TIPPING-BUCKET GAGE.

cepting for the time elapsed between the first and last hundredth recorded.

In very intense rains enough rain may fall during the time required to overcome the inertia of the bucket and water contained therein to produce an appreciable and often considerable deficiency in the recorded amount, although the amount subsequently measured in the brass tube will be correct.

The Friez gage cannot be used in freezing weather or to catch snow. Records of the intensity of precipitation in winter are generally of less importance than in the summer time. They are nevertheless desirable. The Casella tipping-bucket gage, made in London, contains a snow-melting device permitting its use throughout the entire year. Lamps or oil heaters are objectionable for several reasons. There should be no great difficulty, however, where electrical current is available, in arranging an electrical heating coil which would keep the gage interior warm enough to permit the use of a recording gage throughout the year, although the cost of current would be appreciable.

Full descriptions of the numerous types of recording rain gages in use in England and elsewhere are unnecessary here. Some of these, including the Fernley, Halliwell, and Hyetograph, are integrating or float gages and record graphically the total amount of rain which has fallen at any given moment. Such gages are sometimes provided with automatic siphons which empty the measuring tube when a certain amount of rain is caught, and return the pen of the recorder to the zero line. In this way a record having a large vertical scale is obtained on a relatively narrow record sheet. It is nearly if not quite as difficult to determine the exact time of beginning and ending of rain with such gages as with those of the tipping-bucket type. They give, usually, more satisfactory records in rains of very high intensity.

Charles F. Marvin, chief of the United States Weather Bureau, has designed a seven-day recording rain gage of the float type, in which the recording pen traces a spiral line on the record sheet, wound around the drum of the chronograph, in a manner similar to the operation of the Friez tipping-bucket gage. In the Marvin gage, as the rain accumulates in the gage well, the float rises, and the chain connecting the float to a counterweight and running

over a pulley actuates a cam which moves the recording pen laterally back and forth over a range of one-half inch for each one-half inch of rain caught in the gage.

In this way the scale of the record is multiplied by two. The movement of the pen forms a zigzag line changing its direction for each one-fourth inch of rain in somewhat the same way that the pen of the Friez gage changes its direction of motion for each .05 in. of rain. Like other float gages the cumulative inertia error inherent in gages of the tipping-bucket type is eliminated. Like the tipping-bucket gage it gives a fairly precise indication of the time of occurrence of high rainfall intensities. Water enough is left in the receiver to sustain the float, and a layer of kerosene oil is used to prevent evaporation. This gage is not yet on the general market but can be obtained, built to order.

Rain Gages on Board Ship.

The rainfall over the ocean is much less completely determined than that over the land. It is probably subject to much less local variation. Fairly reliable determination of the average rainfall for any latitude and longitude over the ocean can be determined from records made on board ships at sea.

Rain gages for this purpose are furnished by the British Meteorological Office, and the following description of the method of erecting rain gages on board ship is given in the Marine Observers' Handbook (see Fig. 12):

"The instrument is attached to an iron frame, Fig. a, by two bands (bb) which encircle the cylinder, two tubes (tt) forming the sides of the frame.

"A two-pronged fork of bar iron (pp) has an eye (e) formed in the bend of the bar, for use in securing an iron halyard block or gin (g) to the fork and the fork to the stay.

"In Fig. 12, b, the rain gage is shown attached to its frame.

"In the eyes (e'e') at the end of each prong of the fork a 1-in. steel-wire rope is spliced, to serve as guides to the gage, also as guys when necessary.

"The fork is lashed to the stay, at a suitable distance from mast or funnel, at a height of from 20 to 30 ft. above the deck; the two guides are rove through their respective tubes and set up to eyebolts or other suitable fixtures on deck, perpendicular.

"The rain gage is hoisted to the stay by a halyard, one end of which is seized to the lower cross-bar of the frame, the other end being rove through the block pendant from the eye of the fork,

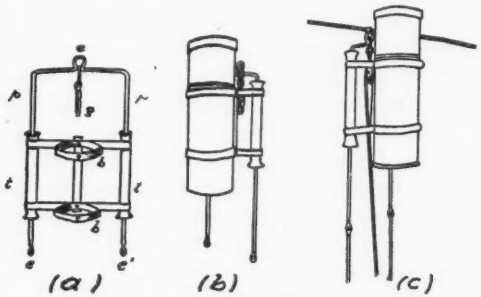


FIG. 12. METHOD OF SUPPORT OF A RAIN GAGE ON BOARD SHIP.
(*a*) Frame. (*b*) Rain Gage and Frame. (*c*) Rain Gage Hoisted to Stay.

and led to the deck. The operation resembles that of hoisting a masthead lamp; the prongs of the fork running into the tubes, which form the sides of the frame, in a similar manner.

"When the frame is hoisted close up to the stay, the rim of the gage will be above it; thus the instrument will have a free exposure, Fig. c.

"Should the gage require steadying when it is in its position and the guides are set up taut, the latter should be released, carried outward, and re-set up rather nearer the ship's side."

SHIELDED RAIN GAGES.

It was early discovered (Heberden, Westminster Abbey, 1769) that rain gages above the ground and unprotected caught less and less rainfall as the height of the gage increased. In 1811, Luke Howard showed by experiment with rain gages placed on buildings and compared with those placed on the ground that the difference was due to the action of the wind. This matter will be discussed in a subsequent paragraph.

In order to remedy this defect, where gages cannot be placed at ground level, the use of garnitures and shields around the mouth of a gage was suggested, first by Thomas Stevenson in 1841. Later, Joseph Henry, in 1853, recommended the use of a horizontal circular time plate, 4 in. or 5 in. wide, and surrounding the gage

funnel. The most successful of shields thus far devised is that invented by Prof. F. E. Nipher, of St. Louis, in 1878. Fig. 14 illustrates a gage equipped with a shield of the Nipher type. The deficiency of catch of an unprotected rain gage increases with the wind velocity, is greater in light than in heavy rains, and is greatest of all for dry snow.

Wild, in Russia, in 1885, devised a rectangular wooden enclosure of wicker work, which has been used quite extensively in Russia. The following table shows the percentage of rainfall as determined by protected gages, which was caught by gages in St. Petersburg between 1891 and 1894. Unprotected gages are compared with gages with the Nipher and Wild shields respectively.

	Ratio — *Unprotected* Nipher Jacket.		Ratio — *Unprotected* Wild Fence.	
Mean Wind Velocity.....	0–3 Meters per Sec.	7 or More Meters per Sec.	0–3 Meters per Sec.	7 or More Meters per Sec.
Dry snow.....	87%	40%	83%	31%
Wet snow.....	92%	80%	86%	80%
Light rain.....	92%	90%	85%	89%
Heavy rain.....	99%	99%	99%	99%

(British Rainfall — 1906.)

In England the usual height of gage funnels is one foot above ground. In the United States, where snowfalls of two feet or more may occur, and on account of the likelihood of interference with ground or pit gages, it is customary to place the rain gage at somewhat greater height. Where a ground exposure is used, a height of funnel of $4\frac{1}{2}$ ft. is convenient, and is about the least which will insure against interference by children and animals.

According to the instructions to observers of the British Rainfall Organization:

"*Site.* A rain gage should be placed on a level piece of ground, not upon a slope or a terrace, and certainly not upon a wall or roof. It should be at a distance from every object higher than itself, and should never be nearer to a wall or house than a dis-

tance equal to the height of that object, nor nearer to a growing shrub or tree than a distance equal to twice that height. Care should be taken to keep flowers or vegetables away from the gage for a distance of at least three feet all around. If a perfectly open site cannot be obtained, shelter is least harmful on the northwest, north and east: but the exposure to southwest and northeast should always be free. The height above sea-level should be determined, if possible, by leveling from the nearest bench mark. The approximate height may be easily ascertained in most cases by reference to the maps of the Ordnance Survey. A specific name should be selected by each observer for his station."

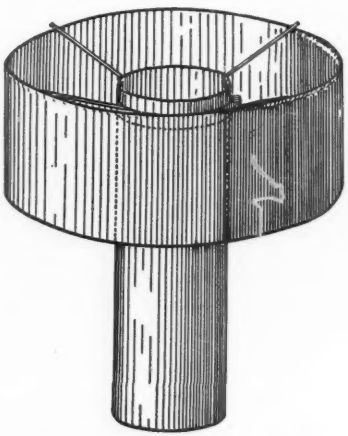


FIG. 13. CLOTH WIND SHIELD.

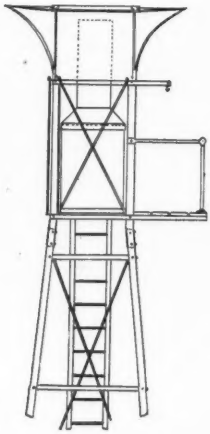


FIG. 14. SHIELDED SEASONAL SNOW GAGE.

"*Mountain and Moorland Sites.* Care should be taken that mountain and moorland gages are not unduly exposed to the sweep of the wind. A level patch of ground or a very slight hollow should be selected, and a turf wall, about 2 ft. high, surrounding the gage at a distance of from 6 to 10 ft. is recommended."

"*Height Above Ground.* The funnel of a rain gage should be set exactly level, and at a height of 1 ft. above ground. If the gage is surrounded by long grass, or likely to become so, the height may be as much as 1 ft. 6 in., but it should never be more." (British Rainfall — 1906.)

"If an elevated rain gage is surrounded by a fence or enclosure, the top of which is the same height as the mouth of the rain gage, and 2 or 3 ft. away from it, the disturbance produced by the wind is greatly reduced, and fairly accurate readings can be secured." (British Rainfall — 1910, page 75.)

The "pit gage" recommended by Symons, stands in an open field at the center of a slight depression of a yard or more in radius. The pit is so hollowed out and the earth is thrown up in a circular ridge on the outside of the pit that the mouth of the gage is on a level with or slightly below the rim of the pit.

Fig. 13 illustrates a rain-gage shield of much simpler construction than the Nipher shield. The results obtained with its use have not been reported. In the United States it is customary, where gages are placed at ground level, to select a location where there are low shrubs or fences having heights about equal to the height of the gage funnel above ground, and at a little distance from it. There should be no taller objects, such as a tree or building, nearer to the gage than a distance equal to the height of the object, or, preferably, at a distance not less than twice the height.

Snowfall Measurement.

The actual measurement of precipitation falling as snow involves so much more difficulty than the measurement of rain as to deserve some special consideration. While an ordinary overflow can of the ordinary Weather Bureau rain gage is commonly used to catch snow, the amount of which is determined in terms of equivalent water depth by methods already described, this procedure is far from satisfactory. As already pointed out, the deficiency in catch of a rain gage is much greater for snow than for rain. The effect of a combination of wind and snow on the catch of an ordinary rain-gage overflow can is shown by Fig. 15. In the storm in which this sketch was made, and which occurred December 26, 1913, at Albany, N. Y., the amount of precipitation as determined from the snow caught in the gage can was 0.43 in., whereas the actual precipitation as determined from a sample of the undrifted snow on level ground was 1.41 in.

To avoid errors of this kind, the United States Weather Bureau recommended that, in case of snowfall or windy days, "the true

quantity must be found if possible by measuring a section of the freshly fallen snow cut out by forcing the overflow mouth downward through the layer, and then slipping a thin board or sheet of metal underneath so as to separate and lift up the section of snow thus cut out." Needless to say, the sample should be taken in

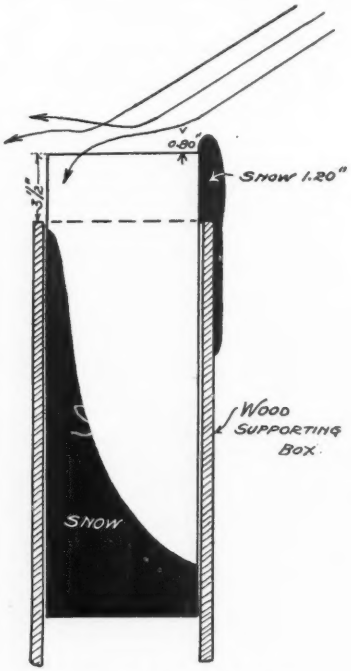


FIG. 15. ACTION OF SNOW OR RAIN GAGE.
Arrows show path of snowflakes.

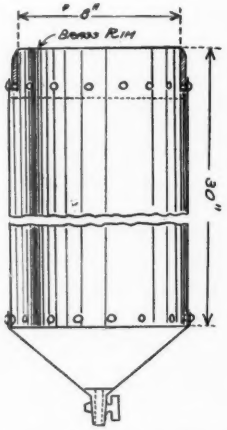


FIG. 16. SECTION OF FRESH SNOW SAMPLER.

a protected place where drifting does not occur. (Measurement of Precipitation, Instrument Division, U. S. Weather Bureau, Bulletin No. 13, p. 9.)

Modified methods and a special form of overflow can, for use in taking samples of snow on the ground, have been devised by the writer. The snow sampler is illustrated by Fig. 16.

A New Snow Sampler.

The edge of the galvanized rain-gage can is not sharp or stiff enough to retain its circular form with certainty when thrust down through deep snow. A special can with a reinforced cutting edge chamfered on the outside and inserted in the mouth of the can will reduce the friction and facilitate obtaining an accurate sample. This can should have a brass drain cock at the closed end, this cock to be opened when taking a sample so as to permit air to escape and prevent the snow being forced out while taking a deep sample by the compression of air in the can. Another advantage of a can with a drain cock is that when the sample is melted with hot water it can be drained out, thus avoiding the difficulty of pouring water from the large can into the brass tube without spilling. The closed end should be preferably made funnel-shaped, with a large, straight-way water cock similar to the bottom of the Friez tipping rain gage. A tight-fitting cover for the open end is also desirable. This may be placed on the can immediately after the hot water is added, and the can set in a warm place, if necessary, to complete the melting of the snow. Cover will prevent appreciable evaporation loss.

This snow sampler can be used either for freshly fallen or accumulated snow. It is also intended to replace the ordinary overflow can of the rain gage, but when so used the bottom ring of the gage funnel must be enlarged to fit over the brass cutting edge of the sampler. When used as an overflow, the drain cock prevents loss by spilling, and is a great convenience. The conical base reduces danger of breakage by freezing.

Select a level space surrounded by shrubs or sparse trees. The open space or clearing should be 50 to 100 ft. or more in diameter, depending on the height of the shrubs or trees. As a rule, snow will not drift nor be blown away near the middle of such a park or open space. In selecting the spot for snow measurement it is preferable to observe the conditions for a year in advance of its use. When snow falls at an angle, as it commonly does, a tree shadows the ground for some distance to the leeward and prevents the full depth of snow from reaching the ground. The spot chosen for making measurements must be sufficiently remote from all trees to avoid an error from this source.

Before the first snowfall, place on the ground a sheet of very thin board — plaster board or beaver board answers well. On the upper surface there should be secured by thumb tacks at the corners a sheet of white cloth with a rough surface — white flannel is good. The position of the board may be marked by two or three stiff wires stuck into the ground at a little distance from the board. When the first snowfall comes, a special snow can, described above, may be inverted over the cloth and pressed down firmly, rotating it slowly as it is pressed down. Then the remaining snow should be brushed off from the cloth, the board lifted, at the same time lifting and inverting the can with the board over its mouth. Having shaken the snow down into the galvanized can, the sample may be reduced to slush or water by adding a measured volume of hot water and then measuring in the brass rain-gage tube in the usual manner used for rainfall and deducting the equivalent of the hot water added.

After a measurement, the flannel cloth is, if necessary, dried, retacked on the snow board, and the snow board placed on the surface of the newly fallen snow where the snow is undisturbed, the board being pressed down just sufficiently so that the cloth surface is flush with the snow surface. The snow board should be inspected every day whether it snows or not, so as to keep its surface flush with the snow surface at all times.

The use of a cloth is twofold. (1) It provides a surface with friction conditions much more closely resembling those of snow than could be obtained by the use of the board alone. (2) It provides a surface as nearly as can readily be obtained, equivalent to a snow surface in its capacity to absorb and radiate heat, and so prevents loss by melting when snow falls in relatively warm air.

Measurement of Accumulated Snow.

The water equivalent of accumulated snow on the ground at any given date is an important factor in relation to the water supply available to fill reservoirs, provide water for public usage, or irrigation, or to produce floods. In order to obtain data from which the available water supply of the coming spring may be estimated in advance, snow surveys have been extensively carried

out, especially in the Rocky Mountain region, during the past few years.

Methods of the accurate measurement of snow in the mountains where it sometimes accumulates to a depth of 20 ft. or more have been developed, but no attempt will be made here to treat those methods in detail. It is not a difficult matter, with proper apparatus, to keep a record, say, once a week of the water equivalent

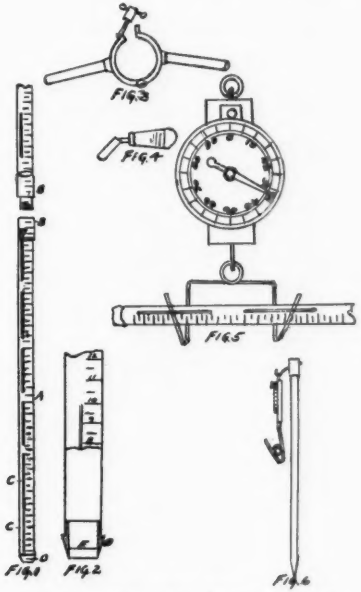


FIG. 17. MT. ROSE SNOW SAMPLER.

of accumulated snow on the ground; and such a record, in conjunction with an ordinary record of rainfall and snow, will afford a valuable check on the latter, and furnish useful information besides.

Among the earliest records of accumulated snow and its water equivalent kept in the United States were those kept by Charles A. Mixer, at Rumford Falls, Me., in 1901 to 1903, and by the writer

at Utica, N. Y., in 1903 and 1904. Apparatus for snow sampling and weighing developed at Utica formed a pattern for subsequent improved apparatus of the United States Weather Bureau. Figs. 17 and 18 illustrate snow-sampling tubes, measuring staffs, and weighing scales of the most improved type.

Before leaving this subject, it may be noted that there is a popular opinion that 1 in. of rain is equivalent to 10 in. of snow, and a method of estimating precipitation in the form of snow,

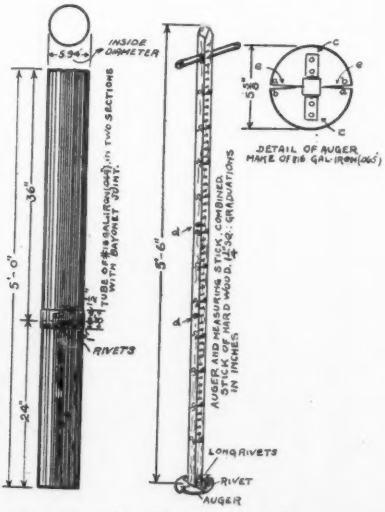


FIG. 18. THE KADEL SNOW SAMPLER.

consisting of first measuring the snow and then dividing the depth by 10 in., is sometimes used. This method is unreliable. The water equivalent of freshly fallen snow varies to a considerable degree. It may range from 1 in. of water to 6 in. of snow, for moist or dense snow, when the air temperature is around the freezing point, to 1 in. of water for 10 or 12 in. of snow at lower temperature. Furthermore, these rules do not apply at all to the accumulated snow, the water equivalent and density of which nearly always increases as winter advances. Commonly, deep

snow lying on the ground for some time will have a density of 0.25 to 0.40, or a water equivalent of 1 in. for $2\frac{1}{2}$ to 4 in. of snow.

Rainfall Duration Records.

Reliable records of rainfall duration are much needed for use in various hydrologic problems, and more attention should be given to the subject of rainfall duration. Records of rainfall duration can, however, generally only be obtained by the use of recording gages, and these for reasons already pointed out are not wholly satisfactory for determining the duration of very light rainfall.

For the purpose of accurately determining rainfall duration, an instrument, which I think may be properly termed an "ombroscope," has been devised by Dr. O. L. Fassig. In this instrument, a sheet of sensitized paper is drawn slowly past an opening by means of clockwork. When it rains, however lightly, some of the drops are quite certain to strike the opening and produce blotches on the sensitized paper, making an autographic record, a sample of which is shown in Fig. 19.

Reading and Inspection of Rain Gages.

The rule of the British Rainfall Organization is that readings should be taken at 9 A.M. In the United States there is no uniform practice as to the time of reading rain gages. The rule for coöperative observers is that the gage should be read at 8 P.M., 75th meridian time — however, many voluntary observers apparently read their rain gages at 5 or 6 P.M. At the regular Weather Bureau stations where recording gages are maintained, the published daily rainfall for twenty-four hours is from midnight to midnight. At many coöperative stations maintained by waterworks officials and others, rain gages are read in the morning. This diversity of practice leads to some inconvenience, where, as is often the case, it is desired to compare the amount of rain in the same storm or on the same day at different near-by stations.

It seems desirable to conform as closely as possible to the rule that the rainfall reported for a given day should be for the period from midnight to midnight. Readings taken in the evening,

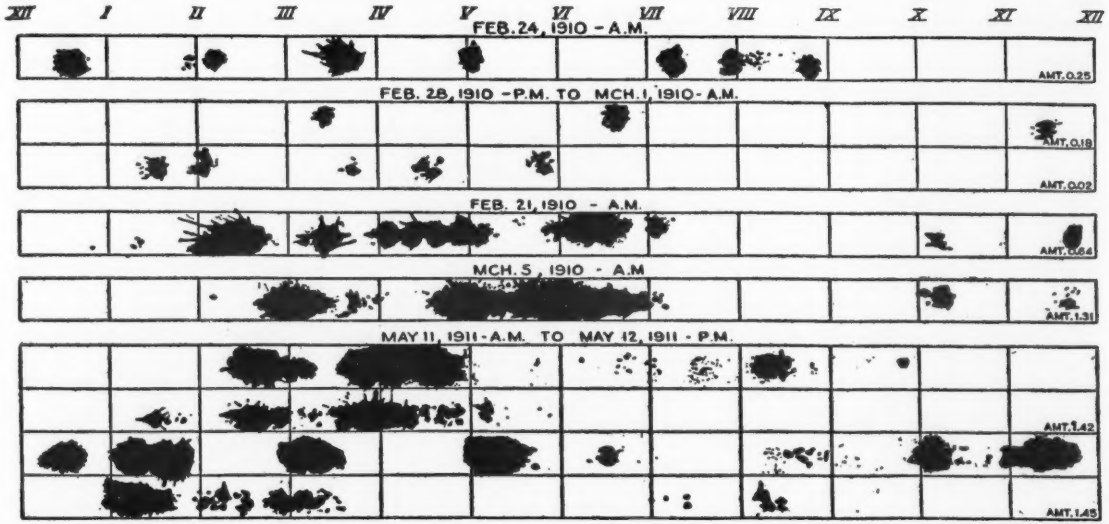

XII I II III IV V VI VII VIII IX X XI XII
FEB. 24, 1910 - A.M.
AMT. 0.25
FEB. 28, 1910 - P.M. TO MCH. 1, 1910 - A.M.
AMT. 0.18
AMT. 0.02
FEB. 21, 1910 - A.M.
AMT. 0.64
MCH. 5, 1910 - A.M.
AMT. 1.31
MAY 11, 1911 - A.M. TO MAY 12, 1911 - P.M.
AMT. 1.42
AMT. 1.45

FIG. 19. RAIN AUTOGRAPH OR AUTOMATIC RECORD SHOWING DURATION AND INTENSITY OF RAINFALL. (Fassig.)

especially those taken at eight o'clock, will compare better with midnight readings, as a rule, than those taken on the following morning, and there is also less liability of confusion regarding the actual day on which the greater portion of rain fell.

On the other hand, evening readings are subject to the objection that throughout the winter period they must be taken after dark. It is not always the rule but it is always desirable that a rainfall observer should inspect his gage at a regular hour every day, whether any rain falls or not. If this is not done, some slight showers are pretty certain to be missed, or included in the next subsequent heavy rain.

With regard to accuracy there is a great difference in observers. An observer should be instructed to report the measured amount of rain to the nearest hundredth inch shown on the cedar measuring stick. If not specially so instructed, the observer is likely to always report the number of hundredths wholly covered by the wetted portion of the stick. In this way the records will contain a small but appreciable error, since, for example, all rainfalls between 1.50 and 1.51 in. will be reported as 1.50. If there are 140 rainfalls in the year, the annual error will amount to a total of .7 in.

One of the easiest ways to determine the care with which an observer is keeping his records of rainfall is to notice the frequency with which he records traces. At any given location, the number of traces of rain (meaning by trace a rainfall less than 1/100 in.) bears a fairly constant ratio to the number of rainfall days. Some observers will be found to omit traces altogether, others record any small amount of rain a trace, and there will be a notable deficiency of measurements of precisely 1/100 or 2/100 in. This condition of affairs invites a strong suspicion that the observer does not read the gage for light rainfall, but simply records a trace. The above remarks point to the necessity of regular and careful inspection of rain gages.

It is also greatly to be lamented that Congress has not seen fit hitherto to provide funds for the regular inspection by Weather Bureau officials of voluntary and coöperative rainfall stations. Pending such provision, those interested in accurate rainfall records may render a valuable service by taking the trouble to

examine any Weather Bureau rain gage they encounter, noting the setting and condition of the gage, interrogate the observer as to his methods, and report the result to the Weather Bureau officials. Regular inspection of rain gages maintained by water-works organizations is equally needful.

A rain gage should always be initially located, or any change of location made, by an experienced man. If a change of location is necessary, it is very desirable that a gage should be maintained in the original location, and another one in the new location, and the records kept simultaneously for one or two years. Continuity of rainfall records greatly facilitates their use. A slight change in the location of a gage may or may not materially affect the results. This fact can be determined by a comparison of gages running in parallel.

Freedom from interruption is also of great importance. Any user of rainfall records knows how troublesome it is to find missing months or years just at the critical time in an important rainfall record. Such omissions can generally be supplied in a fairly reliable manner by methods which need not here be described. A patchwork record is, however, never quite as satisfactory as one that is complete and homogeneous. It is often desirable to instruct two observers at each location, one to act as a substitute in case the other is unable to take the readings for any reason. It may be remarked in passing that women very often make better rainfall observers than men.

Best Size and Type of Rain Gage.

The rain gages now in general use are either 8 or 5 in. in diameter. The Friez recording gage has a 10.5-in. funnel. Gages with 3-in. funnels were formerly sometimes used. The results of some of the more recent experiments as to the relative amount of rain caught by gages of different sizes and types are described in the following paragraphs.

Hellman's Experiments.

The results of Hellman's experiments in 1886 and 1887 are shown in the accompanying tables Nos. 1 and 2. The gages were

TABLE 1.

HELLMAN'S COMPARISON OF RAIN GAGES.

No.	Name.	Actual Diameter.		Catch June, 1886 — March, 1887.		Per Cent. of Gage No. 11.
		M.M.	Inches.	M.M.	Inches.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Von Bezold.....	252.19	9.936	279.8	11.024	96.5
2	Von Bezold.....	252.30	9.941	280.3	11.044	96.7
3	Hellman.....	252.13	9.934	287.7	11.335	99.2
4	Hellman.....	224.85	8.859	285.9	11.264	98.6
5	Hellman.....	195.20	7.691	285.6	11.253	98.5
6	Hellman.....	159.65	6.290	288.0	11.374	99.3
7	Hellman (Conical)...	159.74	6.294	285.4	11.245	98.4
8	Hellman	112.38	4.428	281.4	11.087	97.0
9	Assman.....	252.30	9.941	283.4	11.166	97.7
10	Assman (Conical)....	252.62	9.953	285.6	11.253	98.5
11	Hattinger.....	113.55	4.474	290.0	11.426	100.0

TABLE 2.

NUMBERS OF GAGES GIVING MAXIMUM AND MINIMUM IN EACH MONTH AND RANGE OF DIFFERENCE IN PER CENT. OF CATCH BY GAGE NO. 11.

Month.	Max.	Min.	Per Cent.
June, 1886.....	No. 11	1	5.6
July.....	7	8 and 9	4.5
August.....	11	2 and 8	6.1
September.....	3 and 4	1 and 2	2.3
October.....	11	1	6.6
November.....	11	1 and 7	6.1
December, 1886...	9	1 and 2	7.2
January, 1887....	8 and 11	9	11.1
February.....	7 and 11	9 and 10	4.1
March, 1887.....	6	8	4.3
Total.....	11	1	3.5

set on level ground in a circle $1\frac{1}{4}$ meters between gages, with the gage funnels all $1\frac{1}{4}$ meters (4.10 ft.) above ground. They were surrounded by low trees and shrubs at a distance. They were all cylindrical gages except Nos. 7 and 9, which had conical funnels. The Von Bezold gage had a splayed rim flanging downward and outward from the edge of the funnel on the outside. The gage of smallest diameter, except one, gave the largest catch; and the smallest gage caught more than the largest. The range of error was largest in the winter months.

The Philadelphia Rain-Gage Experiments.

In connection with the Bureau of Water, Philadelphia, an automatic gage having a collector $22\frac{5}{8}$ in. in diameter was used. As there was diversity between the results shown by different gages, experiments were carried out to determine the effect, if any, of variation in diameter. John E. Codman. (Report, Bureau of Water, Philadelphia, 1891, p. 301.)

The following tabulation contains the results of these experiments on similar gages of various diameters exposed at the same height.

BRASS KNIFE-EDGE RIM GAGES.

Diameter, inches	1	2	4	5	6	8	12	24
Catch, relative to 24-in. gage	93	96	100	99	102	102	100	100
Catch, relative to 8-in. gage	91	94	98	97	100	100	98	98

If it is assumed that a gage cannot catch more than true amount unless from outside causes, these data seem to indicate that 8 in. is the optimum size.

The Ithaca Rain-Gage Experiments.

Experiments on different types of gages hitherto used in the United States were made at Ithaca, N. Y., by Alfred M. Wilson, during the years 1908, 1909, and 1910, for the New York State Conservation Commission. The gages used were of the Smithsonian, Fuertes, and DeWitt conical pattern, and they were com-

pared with a standard United States Weather Bureau gage. These gages are illustrated by the accompanying Figs. 2, 3, and 4. One each of these gages was placed on the ground and one of each at an elevation of 10 ft. above ground. The experiments were carried on throughout the open season only. The results, expressed in inches and in percentages of the catch by the United States Weather Bureau gage, are summarized in the accompanying table No. 3.

TABLE 3.

ITHACA EXPERIMENTS ON RAIN GAGES.

Period.	U. S. Weather Bureau 8-in. Gage.	On Ground.			10 Ft. above Ground.		
		Smithsonian.	Fuertes.	DeWitt Conical.	Smithsonian.	Fuertes.	DeWitt Conical.
TOTAL CATCH IN INCHES.							
May — Nov., 1908..	18.84	19.48	19.66	18.75	20.08	19.97	18.03
Apr. — Oct., 1909...	18.68	18.68	18.67	18.16	19.40	19.17	18.20
Apr. — Oct., 1910...	20.74	20.11	20.86	19.67	21.14	21.81	20.16
Total.....	58.26	58.27	59.18	56.58	60.62	60.95	56.39
PERCENTAGES OF U. S. WEATHER BUREAU GAGE.							
May — Nov., 1908..	100.0	103.4	104.4	99.5	106.6	106.0	95.7
Apr. — Oct., 1909...	100.0	100.0	99.9	97.2	103.9	102.6	97 4
Apr. — Oct., 1910...	100.0	97.0	100.6	94.8	101.9	105.2	97.2
Mean.....	100.0	100.0	101.6	97.1	104.1	104.6	96.8

These experiments indicate that the three early types of rain gages experimented upon give results within 5 per cent. of those obtained from a Weather Bureau gage. If the assumption often

made, that a gage cannot catch more than the true amount of precipitation, were correct, then it would appear that the Smithsonian and Fuertes gages must be superior to the Weather Bureau gage. This conclusion is not necessarily correct. It is undoubtedly true that the eddies caused by the wind striking a rain gage, at least a cylindrical gage, tend to blow rain, and especially snow, away from the gage; but it is also true that if wind action causes precipitation less than the true amount in one place, the deficiency there must be distributed as excess over some other area, and eddies around the outside of a gage may possibly cause an excess catch of rain in the gage itself in the case of conical or other non-cylindrical gages.

Whether or not the conical gages, here experimented upon, operated so as to carry into the gage rain in excess of the true amount cannot be stated.

Rothamsted Rain-Gage Experiments.

For several years, 5-in. and 8-in. rain gages have been maintained in conjunction with a gage of one-thousand-acre area at Rothamsted experiment station in England. The results are shown in table No. 4. Taking the catch of the one-thousand-acre gage as unity, the relative amounts are as follows:

5-in. gage	0.967
8-in. gage	0.948
1 000-acre gage	1.000

Considering all the experiments cited, it cannot be definitely stated which is the best type or size of gage. There are, however, good reasons for the preference of the gage of cylindrical form. And when gages of similar form are compared it appears very probable that the one giving the largest catch is most nearly correct. Similar cylindrical gages were compared in the Philadelphia experiments, and these indicate that a diameter of 8 inches is to be preferred; while the Rothamsted and Ithaca experiments and those of Hellman afford some rather strong evidence that an 8-in. cylindrical gage shows about 5 per cent. less than the true precipitation.

The experiments relate mostly to the catch of rain, and, as elsewhere pointed out, much larger errors may occur in the catch of snow. The writer is not ready to accept definitely the conclusion that an 8-in. cylindrical gage catches 5 per cent. less than the true amount of rain when properly exposed, but in view of the evidence presented the matter seems worthy of still further careful

TABLE 4.

COMPARISON OF ROTHAMSTED RAIN GAGES.

Water Year — (September — August, inclusive.)

Year.	5-In. Gage.	8-In. Gage.	$\frac{1}{1\,000}$ Acre Gage.
(1)	(2)	(3)	(4)
1881–2	31.66	30.35	32.31
1882–3	33.69	32.98	34.71
1883–4	25.29	24.44	25.77
1884–5	25.90	25.42	26.78
1885–6	29.46	29.08	31.02
1886–7	22.63	22.29	23.61
1887–8	29.11	28.82	30.50
1888–9	28.79	28.57	30.09
1889–90	26.73	26.30	27.43
Total	253.26	248.25	262.22

experimentation. In the Ithaca and Hellman experiments the gages were not shielded, nor were they at ground level. In the Rothamsted experiments the small gages were one foot above ground. Dr. H. R. Mill, and others in England, have found that a rain gage catches about one per cent. less than the true rainfall for each foot of height of the funnel above ground. Accordingly, all the gages in the Ithaca and Hellman experiments probably show less than the true amount of rainfall; but since all gages were at the same height, the reason why some caught more than others remains unexplained.

TABLE 5.

COMPARATIVE YEARLY PRECIPITATION CAUGHT BY GAGES AT VARIOUS HEIGHTS ABOVE GROUND, ROYAL OBSERVATORY, GREENWICH, ENGLAND.

	Self-Recording Gage.	Second Gage.	Roof of Octagon Room.	Roof of Magnet House.	Roof of Thermometer Shed.	Ground Gages.		
						Magnetic Pavilion.	Observatory Grounds.	
							(1)	(2)
Ht. above ground	50.67	50.67	38.33	21.5	10.0	0.42	0.42	0.42
El. above tide	205.	205.	193.	176.	165.	155.	155.	155.
1903	22.77	23.69	28.75	33.00	35.15	35.54	35.50	35.62
1904	10.95	12.72	16.86	18.90	20.43	20.66	20.33	20.67
1905	12.77	13.25	18.42	20.62	22.87	23.02	22.82	23.40
1906	13.07	13.52	18.66	21.37	23.70	24.74	23.81	....
1907	13.33*	13.74*	17.80	19.40	21.47	22.25	21.58	....
1908	13.76	15.53	19.09	20.84	22.78	23.78	22.74	23.42
1909	15.07*	15.76†	20.33	22.92	25.03	25.71	24.83	25.07
Mean	14.53	15.46	19.99	22.44	24.49	25.24	24.52	25.63
RATIO TO MEAN OF GROUND GAGES.								
1903	.641	.675	.809	.928	.989			
1904	.533	.619	.820	.920	.994			
1905	.553	.574	.798	.893	.991			
1906	.539	.557	.769	.880	.976			
1907	.608	.627	.812	.885	.980			
1908	.590	.666	.815	.894	.976			
1909	.598	.625	.807	.909	.993			
Mean	.580	.620	.804	.901	.986			

* Three missing months interpolated. † One missing month interpolated.

TABLE 6.

JOHN E. CODMAN'S PHILADELPHIA EXPERIMENTS ON THE CATCH OF RAIN GAGES AT VARIOUS ALTITUDES.

Height of Gage — Feet.	0	5	10	15	25	50	Prevailing Wind from			
Side of Mast.		S.	W.	N.	E.	Above and S. E.				
Year.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	NE.	SE.	SW.	NW.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)			
Apr. — Dec., '91	30.52	29.07	30.41	29.96	30.70	29.79	29	15	13	11
Year 1892	39.35	35.41	36.90	36.70	35.65	37.46	43	13	16	22
Mar. — Dec., '93	35.47	33.16	33.23	34.83	32.68	31.68	37	13	17	17
Mar. — Dec., '94	41.58	39.75	39.79	40.55	39.63	38.10	42	26	19	11
Total	146.92	137.39	140.33	142.04	138.66	137.03				

Effect of Wind and Exposure on Accuracy of Rain Gages.

This matter has already been referred to, but may properly be presented in somewhat greater detail.

The table No. 5 shows the results of a comparison of several gages at different altitudes for a period of seven years, from observation at the Royal Observatory, Greenwich, England. These data show a consistent decrease in catch with increased altitudes. The results also show slight difference in the catch of identical gages at ground level. The results of a series of observations with rain gages at different altitudes at Philadelphia are contained in table No. 6. Here again is found a somewhat irregular decrease in the amount of catch as the height above ground is increased. The experiments were conducted by Mr. John E. Codman, and the results are contained in the reports of the Bureau of Water at Philadelphia for the years 1891 to 1895 inclusive.

The gages were freely projected from a common mast on radial arms 10 ft. in length and on different sides of the mast, as indicated in the table. The mast was only 8 in. in diameter, yet rain gages on the windward side caught appreciably more than those on the leeward side.

The following discussion of the effect of wind on the catch of rain gages is adapted from a paper by Dr. Cleveland Abbe (Bulletin No. 7, U. S. Weather Bureau, Forest Influences):

"In the case of ordinary rainfalls we invariably have the air full of large and small drops, including the finer particles that constitute a drizzling mist and the fragments of drops that are broken up by spattering. All these are descending with various velocities, which, according to Stokes, depend on their size and density and the viscous resistance of the air; the particles of hail descend even faster than drops of water and the flakes of snow descend slower than ordinary drops. Now, when the wind strikes an obstacle the deflected currents on all sides of the obstacle move past the latter more rapidly; therefore the open mouth of the rain gage has above it an invisible layer of air whose horizontal motion is more rapid than that of the wind a little distance higher up. Of the falling raindrops the larger ones may descend with a rapidity sufficient to penetrate this swiftly moving layer, but the slower falling drops will be carried over to the leeward side of the gage, and failing to enter it will miss being counted as rainfall, although they go on the ground nearby. . . .

"The action of the wind in blowing the precipitation over to the leeward of the gage depends on velocity rather than on the square of the velocity of the wind and of the raindrop, and it is aggravated by the formation of whirls or eddies within the gage itself by reason of which light and dry snowflakes are even whirled out of the gage after being once caught in it. Similar remarks apply to the rainfall on the top of a large square building with a flat or depressed roof; not only does the top as a whole receive less than an equal area at the ground, but the distribution of rainfall on the roof is such that the least rain falls on the windward portion and the most on the portion to leeward, while somewhere on the roof will be found a region whose average rainfall coincides with that on the ground. But the location of this region will vary with the direction and strength of the wind and the quality of the precipitation, so that we have but little assurance that any single rain gage on the roof will represent the rainfall on the ground. . . .

"If properly protected from the wind, a gage placed at any altitude below the cloud level will unquestionably catch as much rain as one placed at the ground surface — in fact, if there is any difference, the catch at higher altitudes should in most cases be slightly greater, since the ordinary conditions while rain is falling, especially if there is wind, will generally permit of slight evaporation from the falling drops. . . .

"However, it is increasingly difficult to shield a gage against wind action as the altitude increases, since experiments at Philadelphia and elsewhere have shown that the shield itself, if of improper form, may, by forming eddies, decrease the amount of rain entering the gage."

United States Weather Bureau rain gages are commonly placed on roofs of buildings, especially in cities.

A. J. Henry ("Rainfall of United States." Report of Chief of Weather Bureau 1898, pp. 318–19) notes the larger catch observed near the ground compared with the Weather Bureau gages on buildings as observed at St. Louis and Philadelphia, and also the apparently contradictory comparison of the Lower Broadway gage, 150 ft. above the ground, and the Central Park gage, in New York.

Henry says:

"It does not seem possible to avoid the conclusion that the absolute amount of precipitation as registered by the Weather Bureau gages, when placed on high buildings, falls short of the true amount by quantities varying from 5 to 10 per cent. of the true rainfall."

McAdie (Aërography, p. 210) concludes that the catch of rain gages exposed on the roofs of tall buildings in cities where they are almost inevitably subject to wind eddies is too low. He estimates that the recorded rainfall in most American cities where these conditions exist as differing by 30 to 40 per cent. from the amount which could be collected by a gage on the ground. The author does not concur in this conclusion.

There are some cities, as Providence, for example, where such differences certainly exist, but in many other places with rain gages on roofs there is no evidence of deficiency.

From an analysis of 23 records in various places covering an aggregate of one hundred and thirty-five years at various places, showing the relation of the catch of gages at various altitudes to a normal pit gage, Abbe deduced the formula:

$$\text{Percentage deficiency} = 3.32\sqrt{H}$$

where H is the height of gage above ground in feet.

This gives very good agreement with the observed values.

It relates to relatively unprotected gages, — not to gages shielded by the parapet walls of buildings, as are most United States Weather Bureau gages.

In general, if a gage is under suspicion from wind action, it is best to determine the necessary correction from direct observation by Abbe's method described below. This requires the use of a second gage for comparison.

Assuming that the effect of wind is proportional to its velocity and that the velocity varies as the square root of the altitude, then for any single storm,—

$$c_1 = 1 - xH_1R$$
$$c_2 = 1 - xH_2R$$

Where c_1 and c_2 are the actual amounts caught by gages at heights H_1 and H_2, R is the true precipitation at ground level, and x is an unknown wind factor — eliminating x and solving for R, we have —

$$R = c_1 + N\,(c_1 - c_2),$$

$$\text{where } \frac{1}{N} = \sqrt{\frac{H_2}{H_1} - 1}.$$

The following table gives values of the factor N.

TABLE 7.

ABBE'S CORRECTION FACTOR N FOR UNPROTECTED RAIN GAGES.

$\frac{H_2}{H_1}$	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0
1	00	20.488	10.485	7.133	5.458	4.450	3.775	3.291	2.927	2.643	2.414
2	2.414	2.227	2.069	1.936	1.821	1.721	1.633	1.554	1.485	1.423	1.366
3	1.366	1.315	1.268	1.225	1.184	1.148	1.114	1.083	1.053	1.026	1.000
4	1.000	.976	.954	.931	.911	.892	.873	.856	.839	.824	.809
5	.809	.795	.781	.768	.755	.743	.732	.721	.710	.700	.690
6	.690	.680	.671	.662	.654	.645	.637	.630	.622	.615	.608
7	.608	.601	.594	.588	.581	.575	.569	.563	.558	.552	.547
8	.547	.542	.536	.532	.527	.522	.517	.513	.509	.504	.500
9	.500	.496	.492	.488	.484	.480	.477	.473	.469	.466	.463
10	.463	.459	.456	.453	.449	.446	.443	.440	.437	.434	.432

There is another aspect of the relation of air currents to rainfall measurement. It has to do with the general location and topographic surroundings of the rain gage rather than with the details of exposure of the gage.

In any given locality the prevailing rain-bearing winds usually come from some particular quadrant. In New England and eastern United States generally, the direction of wind during rain usually ranges from east or southeast to southwest. A hill, large building, grove, slope, or valley may produce local eddies or currents in rain-bearing winds so that the rain over a particular small space may be constantly less than or greater than the true amount in almost every storm. As a rule, an ascending air current at the surface will prevent the full amount of rain reaching the ground. An eddy with a vertical axis will often prevent the full amount of rain reaching the ground in its interior, but will deposit more than the true amount around its circumference. An eddy with a horizontal axis will often prevent the full amount of rain reaching the ground on the ascending side and will precipitate more than the true amount on the descending side.

The following table illustrates differences of this kind:

TABLE 8.

COMPARISON OF THREE RAIN GAGES, HORTON HYDROLOGIC LABORATORY. August — September, 1918.

Date.	Tipping Bucket No. 1.	Erwin's No. 2.	West No. 3.
(1)	(2)	(3)	(4)
August 5	.55	.52	.59
7	.11	.13	.13
8	.01	.01	.01
9	.03	.04	.04
10	.27	.28	.28
11	.49	.47	.47
15	.15	.15	.15
25	1.50	1.48	1.60
27	.01	.01	.01
29	.12	.10	.12
30	.25	.25	.28
September 1	1.33	1.21	1.36
6	.11	.11	.13
7	.01	.01	.02
9	.06	.06	.06
12	.03	.02	.03
13	.58	.54	.62
14	.09	.09	.09
16	.01	.01	.01
17	.06	.06	.06
19	.63	.65	66
20	.11	.12	.13
21	.81	.83	.90
24	.08	.08	.09
25	.03	.02	..
26	1.13	1.10	1.21
27	.62	.62	.70

Note: Readings taken at 7 A.M.

The three gages referred to are located at the writer's laboratory near Albany.

No. 1 is a Friez recording gage near the crest of a hill on the north side of a deep ravine. Nos. 2 and 3 are standard Weather

Bureau 8-in. gages. No. 3 is located about 500 ft. west of No. 1 on low, gently sloping ground, 50 ft. north of the border of a mill pond. No. 2 is located about midway between the others but on the south side of the ravine, opposite the foot of the pond and south of a grove of large hemlocks which border the south side of the ravine. The gages were all read at the same time and by the same observer, and are all at a height of about 3.5 to 4.5 ft. above ground. No. 3 gage shows, however, a greater catch than the others in the majority of cases.

If a gage is on level ground, remote from trees or buildings, it will usually be subject to somewhat severe wind action, and usually precautions are necessary to provide a proper exposure and shield the gage. If the ground is generally rough or rolling, or the gage is in a built-up district, the wind action may be less severe, but an intelligent and careful study of the situation is necessary to select a location such as to avoid local eddies. No very general or definite rules can be given as to the selection of a gage exposure in the latter case. Good judgment, preferably trained by experience, must be depended upon to afford the best solution in each instance. In studying a situation of this kind, the prevailing direction from which rain-bearing winds will come and the probable effect of irregularities of the ground, or of trees or buildings, in producing eddies, should be carefully studied. In general, a gage should not be placed either in the crest of or in the lee of a ridge running at right angles to the direction of rain-bearing winds.

Errors of Rainfall Measurements.

The usual errors to which rainfall records are subject include, —

1. Observation errors, personal equation, and mistakes.
2. Instrumental or ratio error.
3. Errors due to evaporation.
4. Errors due to inclination of the gage funnel.
5. Wind or exposure error.
6. Location error.

Observational Errors.

The most usual observation error arises from recording the nearest hundredth inch less than the true amount, and from counting as traces all quantities less than .01 inch. If the observer will follow the rule of recording the nearest hundredth inch, whether greater or less than the true amount, and of counting as .01 inch any quantity greater than 0.005 in. and less than 0.015 in., this error will be wholly obviated. As to mistakes, — those of excess are apparently as likely to occur as those of deficiency.

Instrumental Errors.

In the Standard Weather Bureau Rain Gage the cross-sectional area of the measuring tube, when containing the cedar gage stick, should be precisely 1/10 of the area of the gage funnel. If the ratio of these areas is not precisely one to ten, an accumulative error in the records will result. Such a condition is sometimes found, especially in old gages, due to bending or battering the rain-gage funnel. A similar error will result if the measuring stick is not correctly graduated.

If the diameter of the measuring tube and the graduation of the measuring stick are correct, but the rain-gage funnel is too large or too small, then the error in the result will be

$$\text{Error} = \frac{dA}{A} = \frac{2\,\pi r dr}{\pi r^2} = \frac{2dr}{r}.$$

When A and r are the true area and radius and dA and dr the error in area or radius, then for $r = 4$ in. for a diameter of 8 in.:

If $dr = 0.01$ in.,	error $= 0.0025$
0.02	0.005
0.03	0.0075
0.04	0.01
0.05	0.0125
0.10	0.05

Evaporation Loss.

The effect of evaporation is to make the measured less than the true precipitation. The evaporation loss is of two kinds:

1st. From the water contained in the inner gage tube.

2d. Water remaining on the inner surface of the gage funnel after the rain has ceased.

Evaporation from the inner tube takes place from the time rain begins until the time of measurement. The average time from the end of the rain until the measurement is made is twelve hours, and the average duration of rain on a rainfall day is commonly from three to five hours. The average time during which evaporation occurs may be taken as fourteen hours per rainfall day. The average rate of evaporation on rainfall days, as shown by numerous experiments, is about three fourths the average rate of evaporation for all days at the same place and season of the year.

In a case of a United States Weather Bureau rain gage, vapor can escape only from the $\frac{5}{8}$-in. orifice in the gage funnel. An experiment by the writer showed that with 10 in. of water in the inner tube of a Weather Bureau rain gage there was a loss of only 1/10 in. actual depth, equivalent to .01 in. depth of rainfall, for a period of seven days, with a constant temperature of about 70 degrees. At this rate the total loss for a year of 140 rainfall days at fourteen hours per day would be only about 0.12 in. There would probably be but few instances when this loss would cause the observer to record an amount .01 in. less than would have been recorded if no evaporation took place. The loss from this source is negligible.

The drops and film of water remaining in the funnel after the end of the rain and after all the water which will drain out has entered the gage, were found by the writer to have a weight of about 1/10 oz. This is equivalent to a depth of 0.0034 in. of rain. This for one hundred showers a year would be equivalent to 0.34 in. This loss does not occur in the measurement of snow by the usual methods. Here, again, there would be but few instances when effect of this loss would cause the observer to record an amount .01 in. less than the true amount.

Inclination Errors.

Rain gages not regularly inspected are sometimes found standing with their funnels exposed at an angle to the horizontal. This angle may be as much as ten or fifteen degrees. If the rain falls

vertically an inclined gage always catches less than the true amount. If a is the angle of the gage to the horizontal, the ratio of the amount caught to the true amount, in this case, will be as cos a to one. The error for various inclinations is as follows:

5 degrees..... .4 per cent.
10 degrees.....1.5 per cent.
15 degrees.....3.4 per cent.

Rain ordinarily falls at an angle to the vertical of about one or two degrees for each mile per hour, wind velocity; the larger angle-wind ratios occur with small raindrops. The effect of inclination of a rain gage depends on the direction in which it is inclined relative to the direction of the rain-bearing wind. If the inclination of the gage is toward the wind and is less than twice the inclination of the rain, the gage will catch more than the true amount. If the gage is inclined away from the wind it will catch less than the amount for a horizontal gage. In a more general case where the rain comes with a wind not blowing parallel to but at a horizontal angle to the direction of the slope of the gage, let s be the angle of slope of the plane of the gage rim in the direction of the wind, s being negative if the gage is inclined away from the wind. Let b be the horizontal angle between the wind direction and the direction of the slope of the rain gage; then, from a simple geometrical construction, it can be shown that —

$$\tan s = \tan a \cos b.$$

Let r be the inclination of the rain to the vertical, then the relation of the apparent to the true precipitation is expressed by the formula —

$$\frac{\text{Apparent precipitation}}{\text{True precipitation}} = \frac{\cos (r-s)}{\cos r}.$$

If a rain gage is found to be in an inclined position it is important to record the direction of inclination and the direction of prevailing rain-bearing winds. Since the rain does not always come from the same direction it is evident that an inclined gage may give results considerably in error in some showers, and be quite nearly correct in other showers.

There is another matter in connection with the inclination at

which rain falls, which is sometimes of great importance, but which seems to have been generally overlooked. If a rain-bearing wind blows against a mountain slope, then the amount of rain falling on the mountain slope will generally be greater than the amount which would fall on an equal horizontal projected area and greater than the amount caught or measured by a horizontal rain gage.

In a similar manner, the actual precipitation on the leeward side of the slope may be materially less than indicated by a horizontal rain gage. The southeast slope of the Castkill Mountains in New York State affords an excellent illustration of a case where the actual rainfall is apparently greater than the measured amount. The average slope of the mountain side is about 30 degrees. If the rain is blown against this slope at an angle of 15 degrees to the vertical, then the actual precipitation on the prejected area would be 1.16 times the amount measured by a horizontal rain gage.

As already pointed out, the result of wind or exposure error is to make the recorded precipitation usually less than the true amount. The result of error due to location of the rain gage within the influence of a large wind eddy, is to make the recorded amount either greater or less than the true precipitation in the locality.

Taken altogether, there is some preponderance of errors tending to make the measured less than the true amount of precipitation falling as rain, and the tendency is greatly increased for precipitation falling as snow.

If the run-off of a stream for the winter period, November to April inclusive, is compared with the measured precipitation for the same period, it will sometimes be found that the measured run-off is the greater. The ground water and surface storage is usually larger at the end than at the beginning of the winter period, so that the measured run-off will usually represent less than the total available water supply.

If, therefore, the measured run-off is greater than the measured precipitation, it affords evidence that the measured run-off is too great or the measured precipitation too small. There is sometimes a tendency for measured run-off to exceed the true amount during the freezing period. Even where this error is eliminated, cases

still occur which show an apparent run-off greater than the precipitation. It seems probable that in the majority of cases it is due to deficiency in the measured precipitation, which is specially pronounced in the winter and during the fall of snow. Even where measured run-off is somewhat less than the measured precipitation for the winter period, the precipitation may be deficient. The measured run-off should equal the measured precipitation minus

TABLE 9.

COMPARATIVE PRECIPITATION AT DIFFERENT LOCATIONS IN PROVIDENCE, R. I., IN DIFFERENT YEARS.

Year.	Mean of First Five City Gages.	Hope Res. El. 162.5.	Fruit Hill Res. El. 275.	Precipitation Plant. El. 25.	Lockanosset Res. El. 182.	Pittaconset El. 25.	U. S. Wea. Bureau Gage. El. 182.	Ladd Observatory.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1909	38.30	38.13	36.18	37.87	39.38	39.92	33.75	40.57
1910	34.96	36.97	33.96	36.58	33.23	34.07	34.21	37.60
1911	40.17	40.62	39.17	39.72	40.18	41.05	36.80	41.52
1912	41.25	42.84	42.65	39.64	40.18	40.95	38.65	44.37
1913	42.93	44.39	43.32	41.08	42.17	43.68	36.94	45.83
1914	37.58	36.68	37.34	35.19	40.35	38.36	29.50	
1915	42.37	44.61	42.19	40.37	42.56	42.11	33.96	
1916	43,90	47.88	40.56	41.37	44.90	44.82	34.44	
Mean	40.18	41.51	39.42	38.98	40.37	40.62	34.78	

the water losses and minus the gain, if any, in ground water and surface storage.

The winter losses due to surface evaporation and inception in the northern states and New England commonly range from 1 to $1\frac{1}{2}$ or 2 in. per month, with the smaller quantities predominating. The difference between the winter precipitation and measured run-off should, therefore, be at least 6 to 9 in. plus the gain in ground water and surface storage, if any.

Comparative Rainfall by Adjacent Rain Gages.

There are but few locations in the United States where rain gages are sufficiently numerous that a comparison can be made between the rainfall of any single gage and the true mean rainfall over the adjacent district.

TABLE 10.

Comparative Precipitation at Adjacent Rain Gages, Pawtucket, R. I.

Year.	Filter Beds. El. 40.	Pumping Station. El. 90.	Masonic Building. El. 140.	Diamond Hill Res. El. 220.	Mean of Four.	Maximum Departure.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1901	49.29	49.27	46.56	57.56	50.67	6.89
1902	49.23	46.70	47.59	47.56	47.47	1.76
1903	48.67	49.81	47.43	46.08	47.99	1.82
1904	51.16	64.58	48.15	42.94	51.71	12.87
1905	41.56	43.66	42.64	38.39	41.56	−3.17
1906	46.72	51.35	50.39	50.28	49.88	−3.16
1907	44.78	48.11	50.29	46.74	47.48	2.80
1908	44.53	41.86	46.98	42.77	43.53	3.45
1909	41.23	38.41	42.13	40.39	40.54	−2.13
1910	36.86	33.26	38.05	30.78	34.74	−3.96
1911	42.26	39.84	42.06	42.98	41.78	−1.94
1912	45.10	43.55	46.49	44.73	44.97	1.54
1913	44.77	42.76	42.33	44.54	43.60	−1.27
1914	38.73	37.74	38.70	38.25	38.36	−0.62
1915	41.46	41.75	43.75	44.52	43.57	−2.11
1916	43.32	43.81	41.01	46.15	43.57	2.58
Mean	44.35	44.78	44.66	44.06	44.46	0.97

Tables 8, 9, and 10 show the relative amount of rain caught by adjacent gages at three locations in New England. At Providence, excluding the Weather Bureau gage, the results for any other single gage are generally within 5 per cent. of the mean of all the other gages, in any single year. This probably represents about as good a degree of agreement and accuracy as is commonly obtainable from different gages located under favorable conditions.

The low catch for the Weather Bureau gage as compared with all the other gages places it under suspicion. The deficiency is probably due to wind action, the gage being exposed on the roof of a building.

TABLE 11.

RAINFALL AT ADJACENT STATIONS AND DEPARTURES FROM THE MEAN IN PERCENTAGES.

Watuppa Ponds, Fall River, Mass., after A. T. Safford.

	Narrows.	W. W. Pump Station.	Read's.	Pettey's.	Hull.	Bleachery.	Average.
I. — AMOUNTS IN INCHES.							
1899	43.16	40.09	39.56	38.74	47.77	41.47	41.80
1900	43.85	40.87	45.44	40.39	46.77	49.05	44.39
1901	52.77	46.65	53.61	48.07	54.91	57.24	52.21
Mean	46.59	42.54	46.20	42.40	49.82	49.25	46.12
II. — PERCENTAGE DEPARTURES.*							
1899	+3.2	−3.2	−5.5	−6.3	+14.2	−0.7	+0.28
1900	−1.2	−7.8	+2.3	−9.0	+5.2	+9.7	−0.13
1901	+1.2	−5.6	+2.7	−7.8	+5.2	+9.6	+0.88
Mean	+1.1	−7.7	+0.1	−8.0	+8.2	+8.1	

* Percentage departures of the means given in Part I of the table, from the general average.

A roof exposure does not necessarily imply deficient catch. This is illustrated by the comparison of gages at Pawtucket. The agreement is good, although one of the gages is on a building and there is a total difference of 180 ft. in elevation of the different gages.

The agreement among different gages at Fall River is not so good, but represents about what may commonly be expected under less favorable conditions. The differences here are probably mainly due to location errors, and insufficient shielding, as the gages were standard and the observations carefully made.

TABLE 12.

PRECIPITATION AT VARIOUS RAIN GAGES IN THE CITY OF NEW ORLEANS, LA.

Year.	No. 1 U. S. W. B. (Roof). Elev. 71 Ft.	No. 2—U. S. W. B. Audubon "Park." Elev. 4 Ft.	No. 3—Old "A" Dublin. Now at Spruce & Leonidas. S. & W. Bd.—22 Ft.	No. 5—or "C" or Jefferson. S. & W. Bd.—15 Ft.	No. 6—or "D" "Hall" on Roof. S. & W. Bd.—91 Ft.	No. 7—or "E" or "London." 8 Ft.	No. 8—or "F" Now Opelousas St. Algiers.—S. & W. Bd. Elev. 20 Ft.	Mean.	Relation to the Mean.				Mean Departure.	
									Max.	Min.	Range. Inches.	Range Per Cent. of Mean.	Inches.	Per Cent. of Mean.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1895	56.44	66.31	62.99	65.59	56.61	58.84	...	61.13	66.31	56.61	9.70	15.9	3.83	6.3
1896	49.68	56.86	51.60	54.37	51.46	61.18	...	54.29	61.18	49.68	11.50	21.2	3.28	6.1
1897	43.47	54.29	54.54	47.74	46.66	53.93	...	50.10	54.54	43.47	11.07	22.1	4.22	8.4
1898	49.00	69.04	60.43	58.77	54.57	55.41	...	57.87	69.04	49.00	20.04	34.6	4.88	8.4
1899	31.07	43.60	39.58	38.14	33.95	43.03	...	38.23	43.60	31.07	17.53	32.8	3.84	10.0
1900	56.33	71.62	67.51	62.73	57.99	63.66	66.38	63.75	71.62	56.33	15.29	24.0	4.08	6.4
1901	57.73	54.43	54.58	50.46	49.48	52.54	55.94	53.59	57.73	49.48	8.25	15.4	2.37	4.4
1902	41.62	39.11	40.18	38.33	37.04	38.83	34.98	38.58	41.62	34.98	6.64	17.2	1.54	4.0
1903	57.18	47.79	57.09	45.13	51.39	51.96	51.44	51.71	57.18	45.13	12.05	23.3	3.17	6.1
1904	43.69	39.22	39.50	37.22	37.31	38.02	43.51	39.78	43.69	37.22	6.47	16.2	2.18	5.5
1905	80.07	71.97	77.87	69.84	71.09	81.02	77.77	75.80	81.02	69.84	11.18	14.7	4.00	5.3
1906	41.60	44.55	39.56	42.20	41.41	44.22	43.90	42.49	44.55	39.56	4.99	11.7	1.48	3.5
1907	66.32	69.36	63.65	61.33	64.26	64.90	63.49	64.76	69.36	61.33	8.03	12.4	1.86	2.9
1908	51.06	57.10	59.59	59.66	59.94	51.70	51.79	55.83	59.94	51.06	8.88	15.9	3.70	6.6
1909	68.18	68.65	66.50	67.55	66.82	64.82	64.47	66.71	68.65	64.47	4.18	6.3	1.24	1.9
1910	51.50	48.79	45.96	49.90	50.11	54.27	47.94	49.78	54.27	45.96	8.31	16.7	1.90	3.9
1911	67.86	60.73	51.03	66.78	69.04	65.62	64.34	63.63	69.04	51.03	18.01	28.3	4.43	6.9
1912	81.50	80.61	63.77	77.97	81.30	76.67	72.19	72.29	81.50	63.77	17.73	23.2	4.75	6.2
1913	63.64	65.86	68.98	64.88	63.57	59.14	57.52	63.37	68.98	57.52	11.46	18.1	2.88	4.5
1914	54.63	54.92	48.15	48.85	53.62	48.57	50.53	51.32	54.92	48.15	6.77	13.1	2.63	5.1
1915	69.28	73.63	54.56	69.51	67.57	59.74	70.29	66.37	73.63	54.56	19.07	28.7	3.84	5.8
1916	59.44	55.37	45.02	52.29	58.17	47.27	54.86	53.20	59.44	45.02	14.42	27.1	4.29	8.1
1917	40.02	33.07	28.58	34.39	37.06	31.12	38.28	34.65	40.02	28.58	11.44	33.0	3.26	9.4
Mean	55.71	57.65	53.96	54.94	54.80	55.06	56.09	55.45	60.51	49.30	11.21	20.3	3.20	5.9

One of the best series of rain-gage comparisons in this country has been made at New Orleans, the results being shown in Table 11.

It is of interest to determine the agreement obtained from different adjacent gages in a region of excessive precipitation. For this purpose Cherrapunji has been selected. Cherrapunji is located in the Khasi Hills, in the province of Assam, India, facing the Bay of Bengal. The mean annual precipitation is 474 in., or nearly 40 ft. — an average of 110 and 120 in. respectively of rainfall occurring in July and August. There was a maximum precipitation for one month of 208 in., in July, 1865. This is equivalent to nearly 7 in. a day, every day in the month. The heavy rainfall mostly occurs during the summer monsoon season, and is due to the warm, moisture-laden monsoon winds blowing off from the Bay of Bengal, and deflected upward by the Khasi Hills. The general location is shown in Fig. 20, and the location and elevation of five rain gages maintained in the village is shown in Fig. 21. Table 12 shows the relative amounts of precipitation caught by four different gages at Cherrapunji in different years.

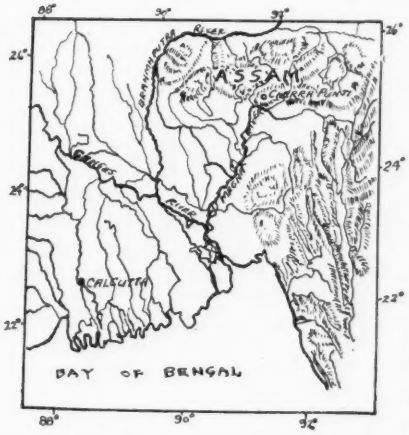


FIG. 20. LOCATION OF CHERRAPUNJI, INDIA.

The average departure of a single gage from the mean of the four gages is 28.56 in. This appears to be a large amount, but it is only about 7 per cent. of the mean rainfall. Very likely this difference is in part the result of actual difference in rainfall at the different locations, due to their varying elevations. On individual days the percentage variations between the several gages are much larger. It is of interest to note, however, that the percentage variation on individual days varies inversely as the amount of precipitation, the agreement between the gages expressed in

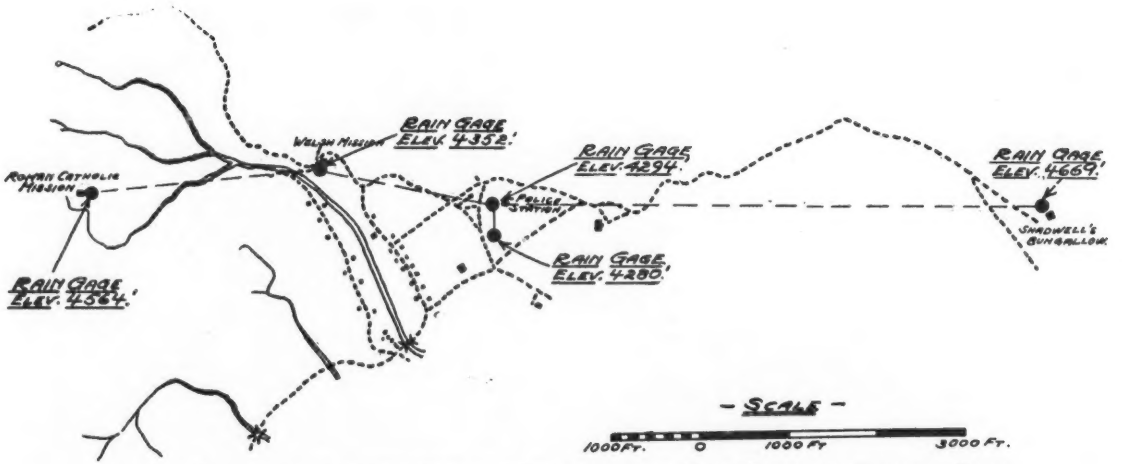


FIG. 21. PART PLAN OF CHERRAPUNJI SHOWING POSITION OF RAIN GAGES AND ELEVATED ROADS.

terms of percentages being much better on days with 10 in. or more of rainfall than on days of very light rainfall.

TABLE 13.

COMPARATIVE YEARLY RAINFALL AT 4 STATIONS IN CHERRAPUNJI, KHASI HILLS, ASSAM, INDIA.

Year.	Stations.				Mean.	Mean Departure.	Mean Departure in Per Cent. of Mean.	Maximum Dep.	Maximum Dep. in Per Cent. of Mean.
	Police Station.	Welsh Mission.	Catholic Mission.	Shadwell House.					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1906	478.54	486.77	445.02	560.09	492.61	33.74	6.85	67.48	13.7
1907	405.92	362.62	310.67	384.67	365.97	29.32	8.00	−55.30	15.1
1908	341.81	284.54	260.21	374.16	315.18	42.80	13.6	58.98	18.7
1909	375.18	334.18	297.77	343.29	337.61	21.63	6.4	−39.84	11.8
1910	561.99	544.88	474.35	519.13	525.09	28.35	5.4	−50.74	9.7
1911	586.57	561.01	488.53	581.13	554.31	32.89	5.9	−65.78	11.9
1912	383.34	390.35	368.57	406.37	387.16	11.20	2.9	19.21	4.9
Mean	447.62	423.48	377.87	452.61	425.40	28.56			

DISCUSSION.

THE PRESIDENT. Are there any questions any one would like to ask Mr. Horton?

MR. DESMOND FITZGERALD.* It seems to me that if there is other business for the afternoon it will be better to get through with that, because the discussion of this paper is likely to take some time, and, perhaps, had better be deferred until a later day. If there is to be a discussion now, however, I should like to take the matter up from the viewpoint of the experiments made many years ago on the Boston water works, and call attention to many points of agreement with the results which Mr. Horton has given

* Past President and Honorary Member, New England Water Works Association; Past President, American Society of Civil Engineers.

us in such an instructive way, and possibly to some points of difference. I think the system of rain gages now included in the Metropolitan supply is an excellent one and gives trustworthy results. I wish also to congratulate Mr. Horton on the industry and zeal with which he has collected so interesting a mass of information, and the trouble he has taken in presenting it to us this afternoon.

THE PRESIDENT. Do I understand you will give us a paper later on the Boston system, Mr. FitzGerald?

MR. FITZGERALD. I will contribute a written discussion of the matter. I am afraid it would take too much time for me to discuss it now.

THE PRESIDENT. We would be very glad to receive your written discussion, or to hear you now, just as you prefer.

MR. FITZGERALD. In regard to this question of altitude of gages above the ground, we built something like eight towers at Chestnut Hill Reservoir some thirty years ago. The gages were so placed that they covered the idea of comparing the results with a pit gage placed level with the surface of the ground. From that point we had gages every five or ten feet up to eighty feet in height. The gages were especially designed to collect the rain so that no loss could take place from evaporation, but they were freely exposed to the wind. Those experiments were kept up for about three years, if I correctly remember, and the lower gages gave the larger results; a result due, I believe, to the action of the wind on the upper gages.

I will say one word now, while I am on my feet, in favor of the system of weighing as against measurement. We found in the course of our investigations that it was easier for an observer to make a mistake in measuring the rain than it was where a proper system of weighing was used. Our gages on the Boston water works were so designed that one one-hundredth of an inch made one ounce in weight. That is to say, the gage was 14.85 inches in diameter; and in a gage of that diameter every .01 of an inch equaled an ounce. The gages were weighed on a common Fairbanks scale and the figures on the scale altered to read hundredths of an inch instead of ounces. That is, 32 oz., for instance, was .32 of an inch and 152 was 1.52 in. of rain. The Fairbanks scales did

not have to be re-made, but simply numbered differently to read inches and hundredths. We got very accurate results from this weighing system.

From an examination covering several years I came to the conclusion that it was extremely difficult to design a gage for both rain and snow, and I gave it up; but we got good results in our measurements of snowfall by the following method: We had a platform on the ground in a clearing in the woods, so that the wind did not affect the results materially. We went to that platform after every snowfall and inverted our gage over it, — there was a piece of tin underneath, — and got all the snow and weighed it. Then we swept off the platform so it was all ready for the next snow. We didn't have snowfalls superimposed one on another.

There is at Chestnut Hill Reservoir a self-recording rain gage that I designed thirty years ago which has been working ever since, and I don't think it has ever had any serious repairs. The results on the sheets are extremely interesting because they are all plotted to good scale and do not require to be interpreted. I hope, Mr. Horton, that you will have an opportunity to examine them while you are in this neighborhood. You will find some very remarkable rainfalls recorded, taken with great accuracy. A cross-section of the apparatus has been published. It is simple and cannot easily get out of order but it is not adapted to the measurement of snow. From the profiles one can study the progress of storms, as they are already plotted to a convenient scale.

The matter of the rainfall always was an interesting one to me. When I first came on to the water works — I think it was in 1873 — I began a serious study of the subject. The gages are made in such a way as to last many years, and they are not easily put out of commission. For instance, you take the average of several gages on the Sudbury River watershed and they must give a close approximation to the mean. As I remember, there was not a great deal of difference between them. The results at that time were quite different from the observations which were taken on one of the high buildings here in Boston. Our records at Chestnut Hill Reservoir were more trustworthy than the

Government records on a high building. There was quite a difference between them, and I think the officials at that time accepted ours as being more accurate. The amount of it is that when you put a rain gage on the top of a high building in the city you get so many whirls of the wind in every direction that it affects the record materially unless some especial precautions are taken, whereas if your gage is properly placed near the ground it is not subject to the same disquieting influences.

THE PRESIDENT. I am very sure that the Association will be glad to put their time against Mr. FitzGerald's, if he will prepare a paper for us on the subject.

MR. R. C. P. COGGESHALL.* We have a wonderful record in New Bedford, what is known as the "Rodman record," that extends considerably over one hundred years. The old gentleman took up the matter as a plaything, years ago, and then his son carried the work along, and when the water works came into existence the work was continued more or less. One of the daughters of the family is Mrs. Colonel Goethals, and it was rather a scientific family.

Our records are kept at the pumping station. We have a set of weighing gages, — and during the past year have got a record there of only a trifle over 36 in., which is the smallest since 1914. It is no wonder that our water supplies are rather short at the present time. The city engineer keeps a record on top of the municipal building, and for some reason he doesn't get anywhere near as much rainfall as we do.

MR. FITZGERALD. The rainfall in the Philippines has been referred to. Benguet is not exactly on the side of a mountain. It is what is called the summer capital of the Philippines and is about 5 500 ft. above the sea. It is on an elevated plateau in a mountainous district.

There is great diversity within short distances in this matter of rainfall. On the Pacific coast, in Oregon or in Washington, we have a rainfall of perhaps 90 in. from the warm Japanese current. That moisture is carried by the westerly winds up the

* Past President, New England Water Works Association; Superintendent, Water Works, New Bedford, Mass.

cold sides of the mountains, and precipitated in the form of heavy rain. It is that large rainfall that produces the big trees, and not the trees which bring the rain. When the clouds get on the other side of the mountains they have no more rain to precipitate, and we have a much smaller rainfall on the easterly side. I remember the enormous records of rainfall in the Calcutta region referred to by Mr. Horton, where they have a record of over two feet of rainfall a day for three days. Of course it is utterly useless to try to keep bridges over the rivers in view of such rainfalls as that. You must simply have an open outlet to the sea for it.

Mr. Charles W. Sherman.* With reference to the difference between the rainfall measurements on high buildings and those on the ground, I have recently had opportunity to make an extended comparison between the record of the recording gage at Chestnut Hill Reservoir and that at the station of the Weather Bureau in Boston. The latter does not cover so many years by fifteen as the former does, but the comparison was made covering just the same period at Chestnut Hill as the entire period of the Boston record. The same storms, or storms coming on the same day, were found to differ very widely. It might very well be so, the gages being five miles apart, more or less. But it is very interesting to note that throughout the period covered by the records, which I think is something like twenty-six years, the average results are substantially identical. I do not mean that closely comparable results were necessarily obtained for particular storms, but that the relations between time and intensity of precipitation, and the frequency of storms of various iutensities, agreed very closely. I am inclined to think that that means that the Weather Bureau, beginning about the time of the installation of the recording gage in Boston, has taken very much more pains in the setting and adjustment of its gages on high buildings in the larger cities than it did in the earlier years. I think that the criticism of the rain-gage records on high buildings in early years is amply justified, — I think they are entirely untrustworthy, — and I think many of them at the present time are, unless they are very carefully safeguarded. I have the impression, however, that the

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

Weather Bureau in its important stations has given much more attention in the last twenty-five years to protecting its gages by screening or otherwise, and that such gages generally now give results much more trustworthy than those of the earlier years.

MR. X. H. GOODNOUGH.* I hope, Mr. President, that Mr. FitzGerald will print his experiments in the Society's publication. I think they are among the most interesting, in fact, decidedly the most interesting and most valuable ever carried out in this state, and it seems to me it would be a very great aid to all the members of the Association if he would be willing to prepare them for publication in the Society's JOURNAL. They cover the whole range of the subject, and bear especially on this question of elevation.

There is one other point I should like to emphasize again, which was brought out in the paper, and that is the extremely small number of rainfall stations in New England. I think half of the whole number are in Massachusetts, and more than half of those are in eastern Massachusetts. The number is increasing, but even now there are very wide spaces in which no rainfall station exists.

The study of rainfall was very well begun by the New England Meteorological Society in 1884. They maintained for a time a journal, and did the first work which was important or successful, it seems to me, on this subject. Of course the work was begun in many ways years before that. I think that the Government began to make observations of the rainfall in the very early part of the nineteenth century, and there are a lot of those old records now in existence. Then I think there was a law in the state of New York under which observations were made at all the academies, for many years. Later on, the enthusiasm in the measurements of the rainfall dropped off. Then the Government came in again, but does not maintain stations enough to furnish satisfactory records of the rainfall in many of the watersheds. It seems to me that the Government is not especially to blame, but that it is we who are to blame for not urging them and for not insisting on a greater number of observations, and then helping in every

* Director and Chief Engineer, Mass. State Department of Health.

way that we can. The question is a very important one, especially now when questions of waterways development and power development are coming up, and it is not too late to begin even now to try to secure a greater number of observations.

SOME PRACTICAL USES OF RAINFALL RECORDS.

BY L. M. HASTINGS, CITY ENGINEER, CAMBRIDGE, MASS.

[*Read February 12, 1919.*]

At the December meeting of the New England Water Works Association, a letter was read from Robert E. Horton suggesting that an effort be made to get officials in charge of water works to establish rain gages at the watersheds upon which their water supply depends.

While there are a fairly good number of rain gages established in various parts of New England now, the number might be greatly increased with good results, especially if they were established in locations not already closely covered by existing observers.

The accompanying map, reproduced from that given in a paper by Mr. X. H. Goodnough, on "Rainfall in New England," JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, Vol. XIX, No. 3, shows the location of most of the rain gages as in service in 1914 — about 194 in all. It will be observed that the southeasterly corner of New England is well supplied with rain gages, but that there are in the remaining sections of New England large areas where the gages are very widely separated. Many of these sections are well elevated, with many streams, and opportunities for reservoirs, dams, etc., for the development of power or water supplies. (See Fig. 1.)

If, as is recommended so strongly at the present time, a careful study of the streams and water courses of the country is to be made with a view to their more complete development as a source of power in order to conserve the consumption of coal as a power producer, the establishment of numerous rain gages in various parts of the country will be found exceedingly useful in the study of that important question, as well as the one in which the members of this Association are more directly interested, viz., the development and conservation of our streams as sources of domestic water supplies.

It is proposed in this paper to give a few simple illustrations of ways in which rainfall records may be put to practicable use in

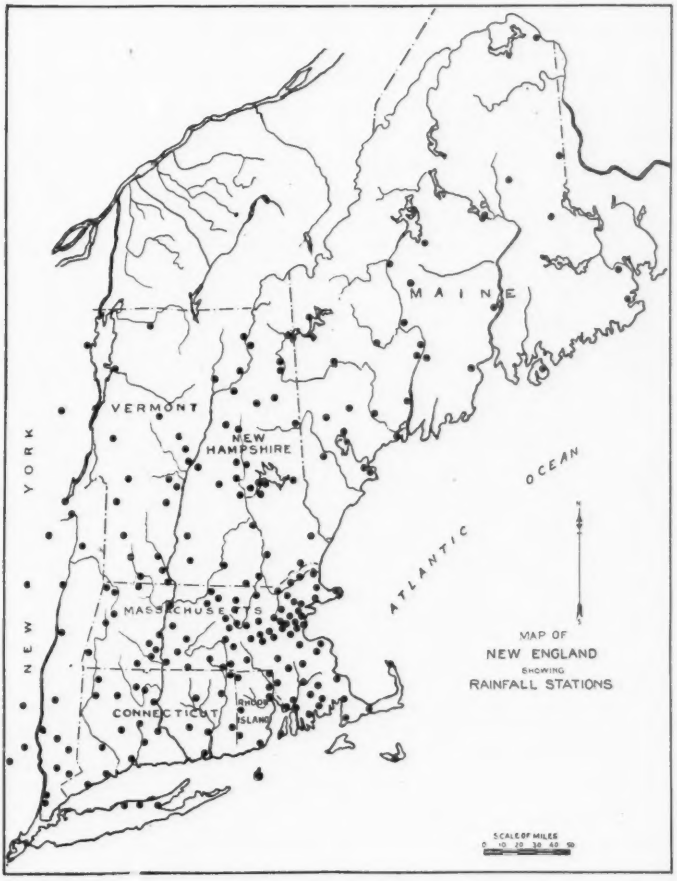


FIG. 1.

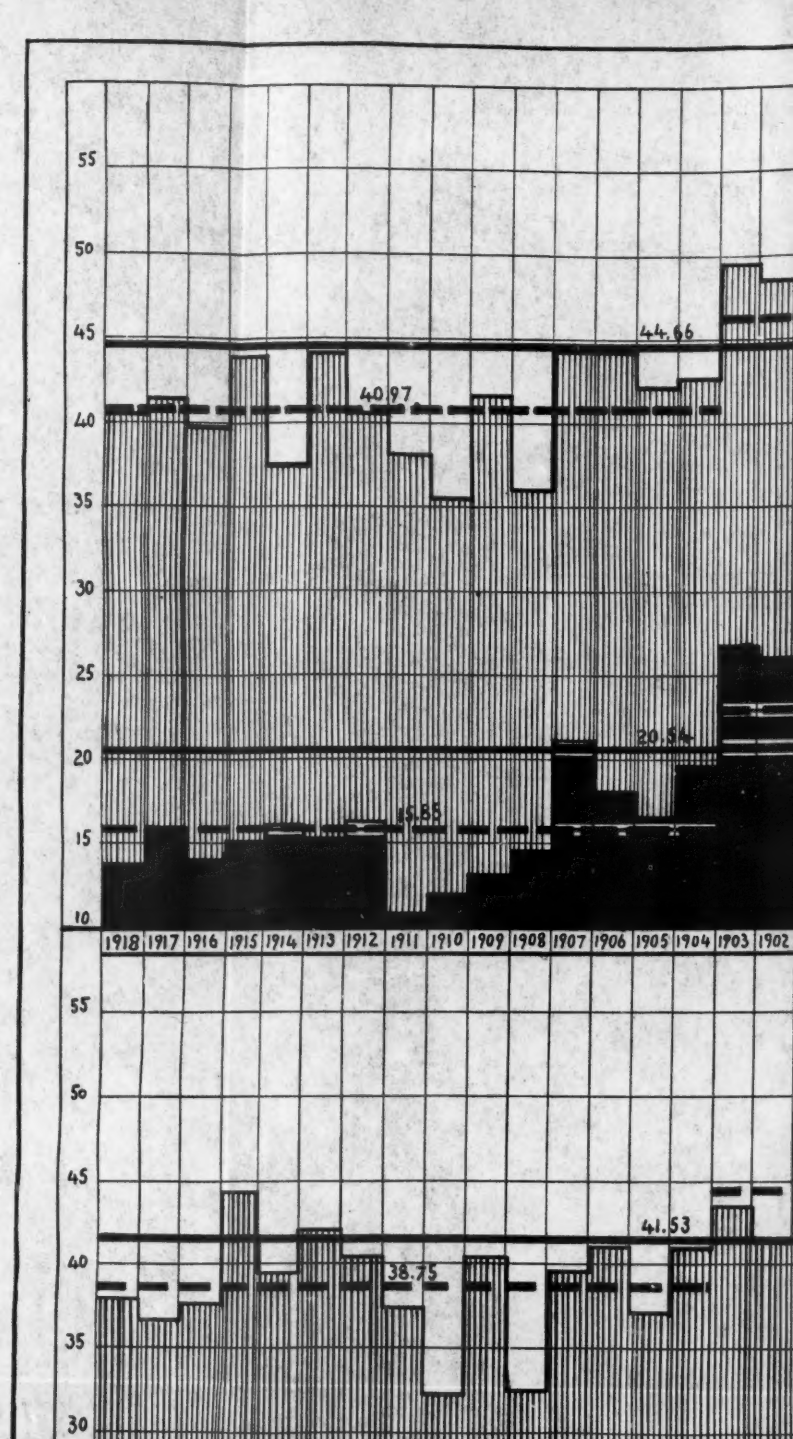
the study of questions relating to water power and water supply, and so encourage the establishment of additional gages.

One advantage to be gained by having gaging stations located at relatively short distances apart would be to check the results so obtained by those obtained at other stations and correct any variation which may appear in the gaging due to special or unusual topographical conditions in the watershed, such as elevation, nearness to large hills, mountains, or water surfaces, directions of prevailing winds, etc. As the amount of rain which may be expected to fall in a given district is often the only basis upon which its value as a power or water producer can be found, it follows that it is desirable to have the very best data that it is possible to obtain on that vital point.

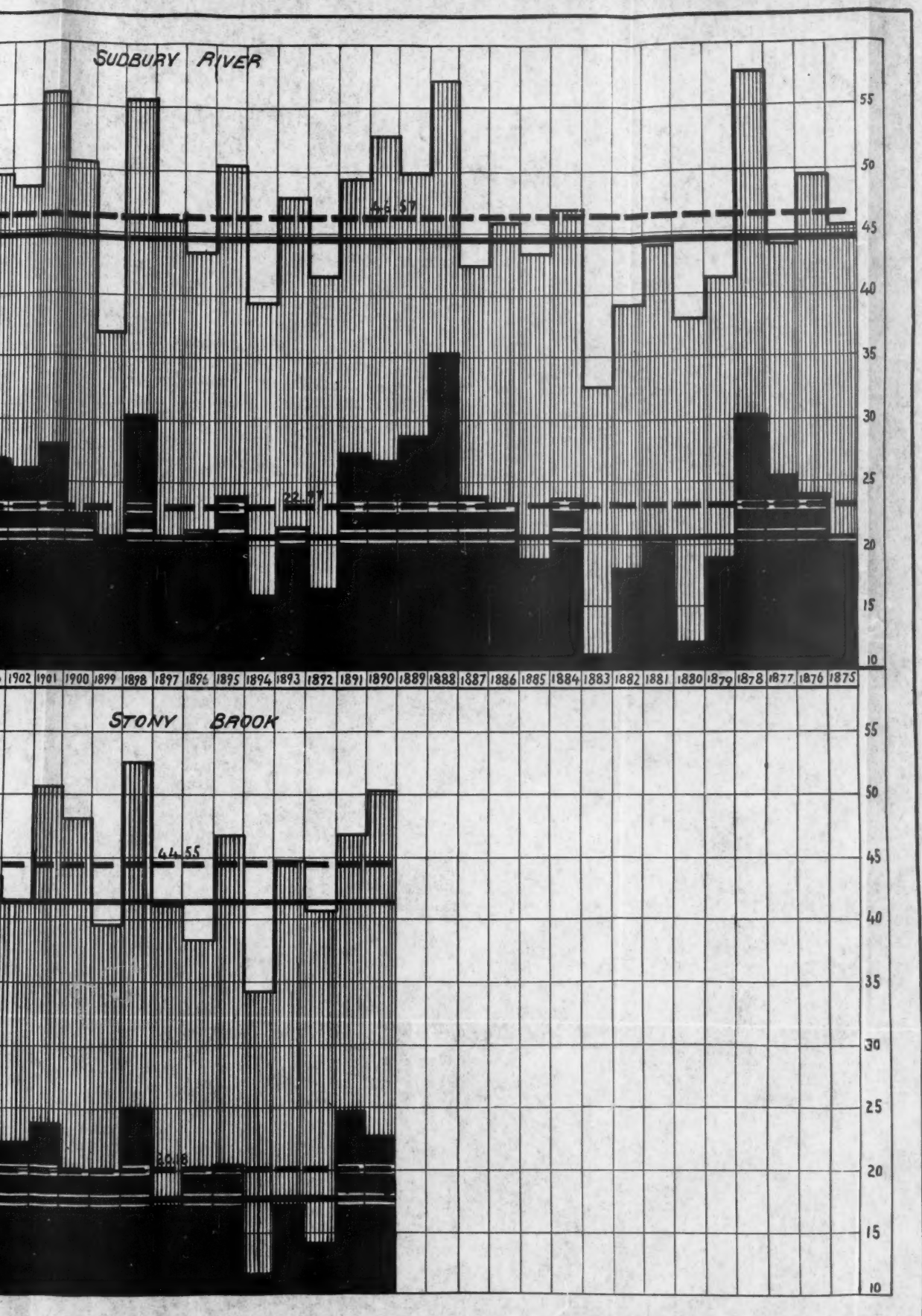
It may be thought that with so many rain gages already set up, especially in eastern New England, it would be easy to obtain

Location.	Average Yearly Rainfall, 1874–1913, 40 Years.	Rainfall for Year 1880.	Rainfall for Year 1883.
Manchester, N. H.	38.27	27.30	31.47
Concord, N. H.	38.63	30.48	31.35
Lowell	42.01	35.28	39.84
Waltham	43.36	31.73	29.32
Cambridge, Harvard College	43.49	35.22	32.65
Framingham, Sudbury River	44.26	37.87	31.95
New Bedford	46.65	40.06	43.51
Providence, R. I.	47.20	41.29	39.54

accurate and reliable data for almost any location in that section; but any one not familar with the subject will be surprised and puzzled at the wide variation in the results obtained at locations not far apart, which often renders any close estimates impossible. As illustrating this fact, the above table has been prepared showing the average rainfall at various stations in eastern New England for a forty-year period ending 1913, and also the rainfall for the exceptionally dry years of 1880 and 1883, which for some purposes it might be desired to use. Manchester, N. H., and Providence, R. I., are only about eighty miles apart in a straight line.


55
50
45
40
35
30
25
20
15
10
44.66
40.97
20.54
15.85
1918 1917 1916 1915 1914 1913 1912 1911 1910 1909 1908 1907 1906 1905 1904 1903 1902
55
50
45
40
35
30
25
20
15
10
41.53
38.75
17.31
15.12

RAINFALL (I



L (INCHES) ON SUDBURY RIVER AND STONY BROOK WATERSHEDS.

From the above it will be seen that even for a long-term period the average amount of rainfall at the points named varies greatly, the extreme variation being 8.93 in. or about twenty-three per cent. while for the dry year of 1880 the extreme variation is 13.99 in., or over fifty per cent. From this it will be seen that any one attempting to design a water-power or a water-supply system for a watershed at all remote from a long-established rain gage must unavoidably make his estimates upon data which have a large element of uncertainty in the makeup.

It has been stated by some writers that a rainfall record of from thirty-five to forty years makes that record fairly reliable as a basis of estimates for the expected average yield of a watershed. While this may be true for an ordinary forty-year period, an examination of the rainfall records of the last forty years of the Sudbury River watershed, and others which have commonly been used in this vicinity, shows that a marked change in the amount of rainfall has occurred during the last fifteen years of that period, and that, while the average for the forty-four years since the Sudbury River records were begun is 44.66 in., the average for the period 1904 to 1918 (fifteen years) is only 40.97 in. (See Plate I.)

The Stony Brook rainfall record of the Cambridge Water Works in Waltham, Mass., shows a similar change. While the average rainfall for the entire period of twenty-nine years the gage has been established — 1890 to 1918 — is 41.53 in., the average for the period 1904 to 1918 (fifteen years) is 38.75 in.

These last are remarkably low average rates for so long a period, and there seems to be but one period of that length of time with so low a rainfall record in this vicinity. This is the Cambridge record of Prof. John A. Winthrop, from 1760 to 1775, where the average rainfall is shown as 37.38 in., as given by Mr. Goodnough in his paper already referred to.

Still further, the record of the yield or run-off for both these areas shows a corresponding persistent decrease. While the average run-off from the Sudbury River area for the forty-four years is 20.54 in., the average run-off for the last fifteen years is 15.85 in. On the Stony Brook area, the average run-off for the twenty-nine years is 17.81 in., and the average run-off for the last fifteen years is only 15.70 in.

If these records are analyzed by percentages, the interesting fact is shown that in the dry periods the *proportion* or *percentage* of run-off to rainfall is less than that in the wet periods. Thus, for the wet period in the Sudbury River area, 1875 to 1903, the run-off was 49.3 per cent. of the rainfall, while for the dry period 1904 to 1918 it was only 38.7 per cent.; while for the exceptionally dry year of 1883 it was 34.1 per cent., and for the year 1911 it was 28.1 per cent. Similarly, on the Stony Brook area, for the wet period 1890 to 1903 the run-off was 42.9 per cent. of the rainfall, and for the dry period 1904 to 1918 it was 40.5 per cent., and for the year 1910 it was only 27.1 per cent. of the rainfall. In other words, a diminished rainfall gives not only a diminished run-off, but a *diminished proportion* of run-off. From these facts, it is evident that it may not be safe to draw conclusions even from a forty-year record, without a careful study of the records of other places and other periods, that proper allowance may be made for abnormal results which may have been obtained.

There is another rather curious fact shown in the records for the year 1909 which may be noted. While the rainfall for this year is about 6 in. more than for either the years 1908 or 1910, the *run-off* for 1909 is about 1.50 in. *less* than for the year 1908. The Stony Brook record shows the same peculiar result, — a lessened run-off in a year of increased rainfall. The explanation of this anomaly may be that the underground storage had become so depleted by the continued drought of a number of years that the increased rainfall for the one year failed to restore the deficiency in this storage and so caused a lessened run-off for that year.

A very important and interesting question may be raised just here. Will the diminished rainfall as noted during the last fifteen years be permanent or will the rate " come back " to its old level? While no definite or authoritative answer can be given to this query, two things should be remembered in this connection. No permanent marked changes ever take place in the processes of nature without adequate cause. No such adequate cause is apparent by which the rainfall of this section could be permanently diminished, and again, in the past marked changes have occurred in meteorological conditions, — cold winters, hot summers, wet and dry seasons, — some continuing for considerable lengths of

time, but inevitably the balance has been restored and the general mean of conditions reëstablished. Even if the period of low rainfall given in Professor Winthrop's somewhat fragmentary records be taken as reliable as showing the entire rainfall for that

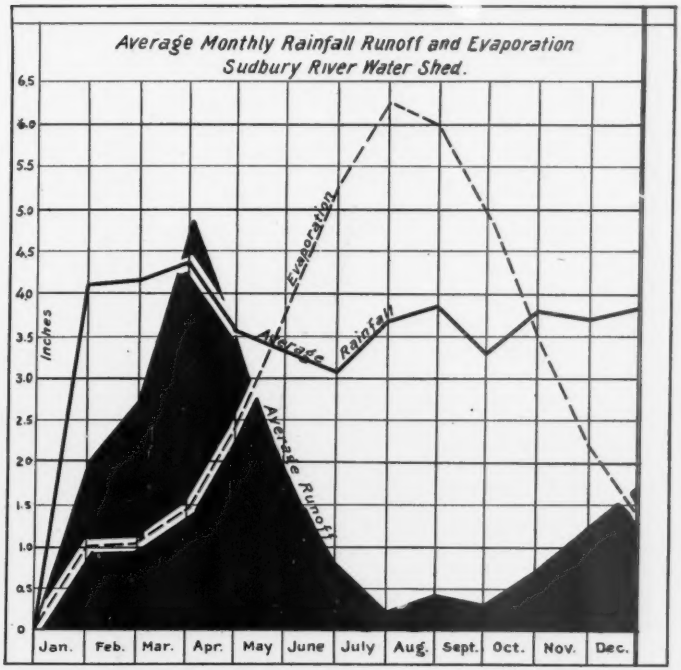


FIG. 2.

period, the records of other observers for following years show the amount of rainfall to be well up to or above the average.

A very practical and convenient way of using the daily rainfall records is by plotting them in the form of a mass diagram. Probably one of the most common inquiries a superintendent of water works has to answer is one relating to the condition of the reservoir as regards the supply in storage. Much misconception frequently

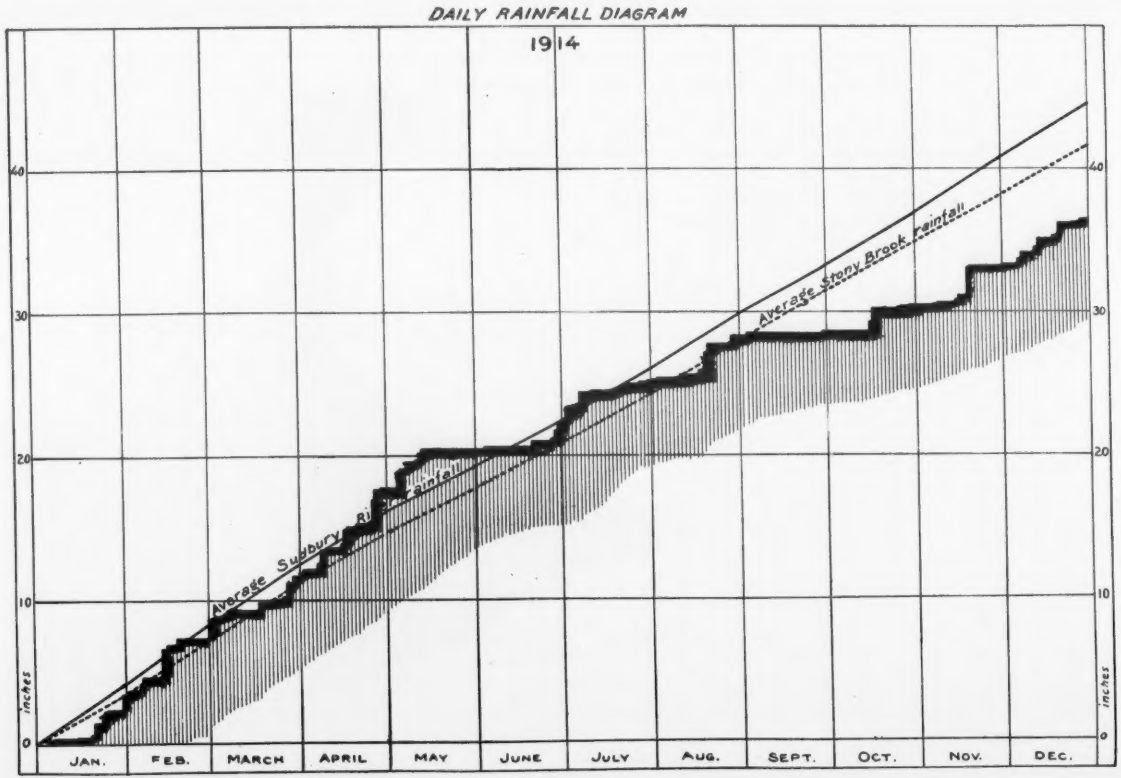

DAILY RAINFALL DIAGRAM
1914
40
30
20
10
0
inches
Average Sudbury Rainfall
Average Stony Brook rainfall
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.

FIG. 3.

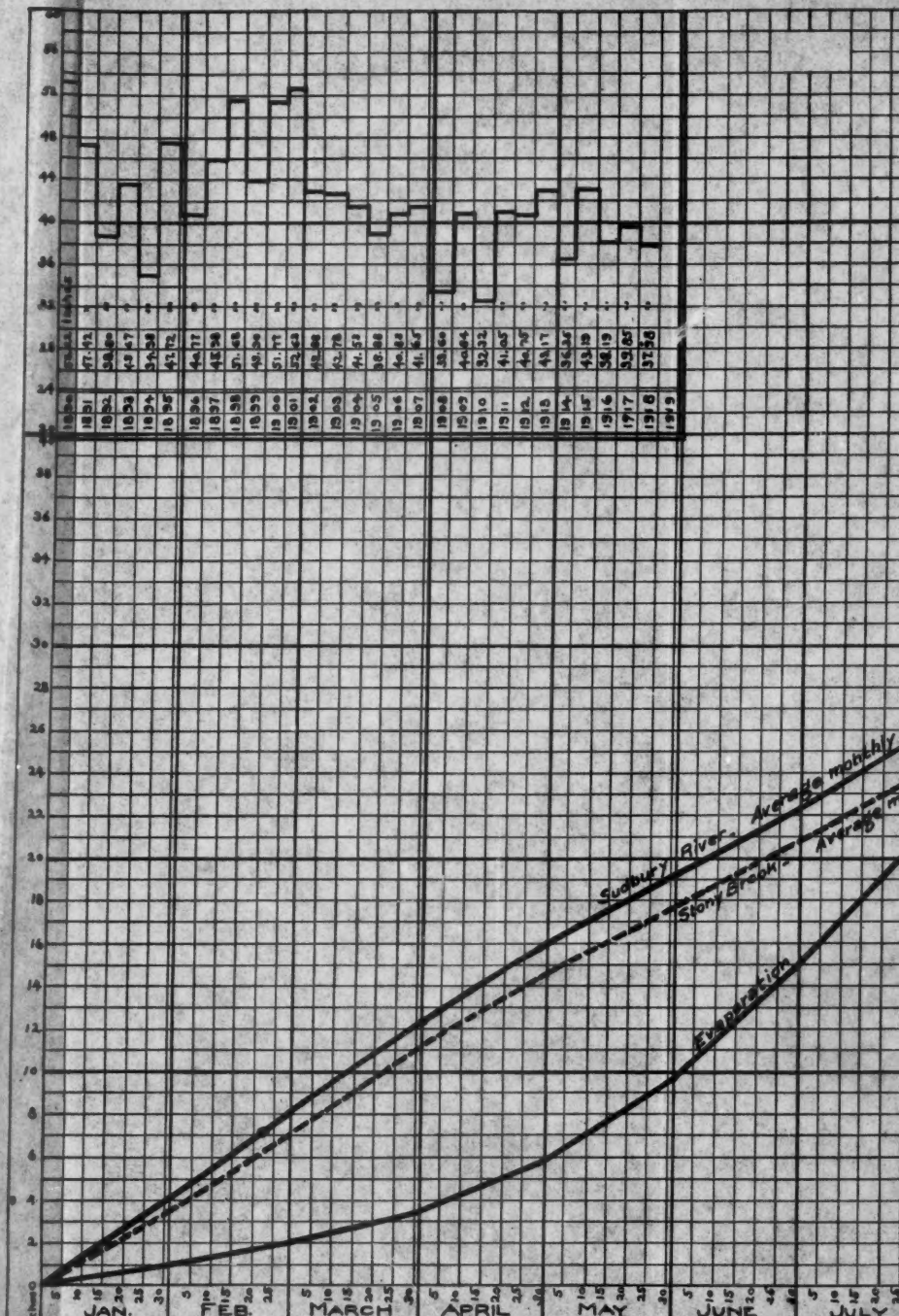
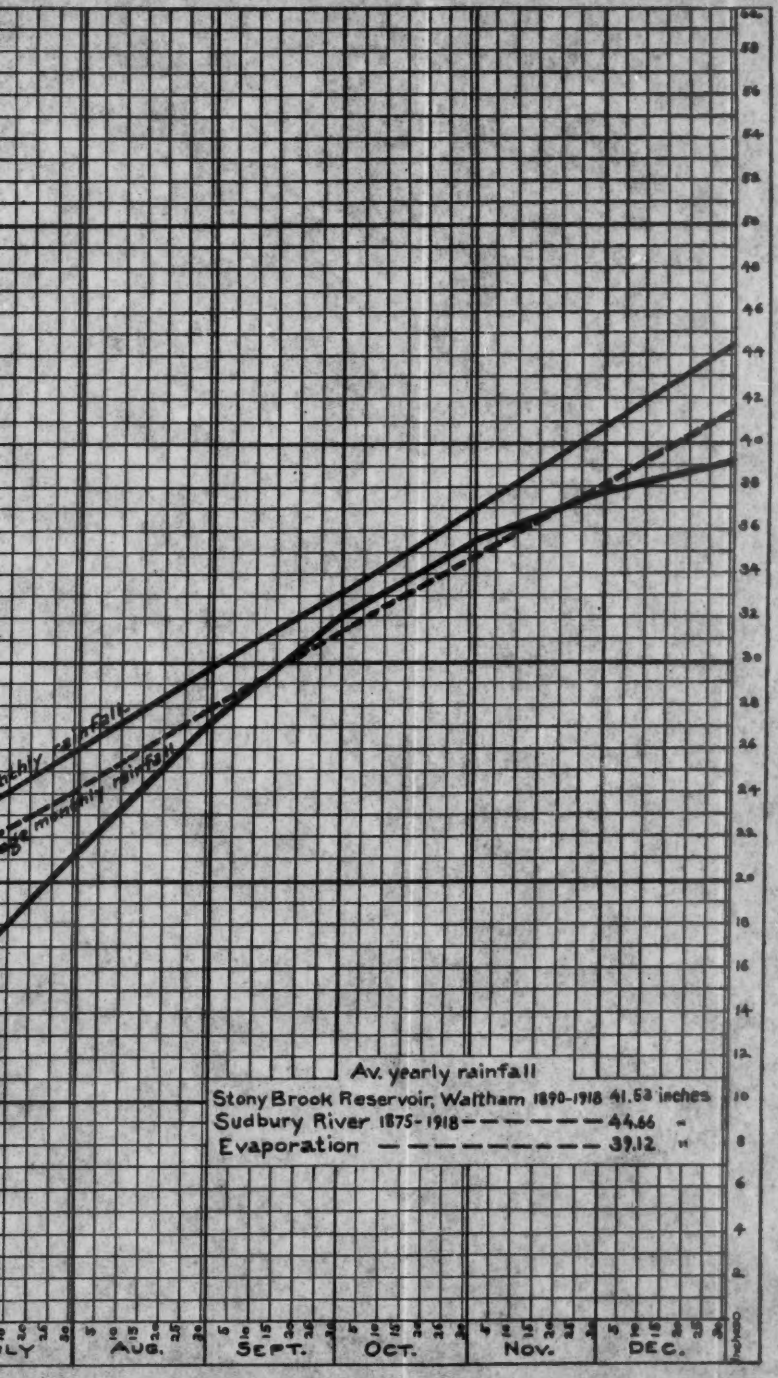

Inches
Mean Inches
1880 1881 1882 1883 1884 1885
47.42 38.60 43.67 34.58 47.72
1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897
44.17 45.58 51.46 48.34 51.71 52.43 48.88 42.78 44.52 48.05 38.86 40.82 41.65
1898 1899 1900 1901 1902 1903 1904 1905 1906 1907
38.60 40.64 32.32 41.05 40.75 43.77
1908 1909 1910 1911 1912 1913
36.45 43.19 38.19 39.85 37.58
1914 1915 1916 1917 1918 1919
Sudbury River.
Stony Brook.
Evaporation
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY

PLATE II.
N. E. W. W. ASSOCIATION.
VOL. XXXIII.
HASTINGS ON
RAINFALL RECORDS.



exists in the " average citizen's " mind as to the amount of rain which has fallen to a given date, and consequently as to the amount of water which has been received into the storage basins.

If the returns are plotted on the prepared skeleton or frame of the diagram at weekly or monthly intervals, a glance will show just how the matter stands with regard to the total amount of rainfall to date, and also whether that amount is more or less than the average amount of rainfall up to that time. (See Plate II.)

It is rather a curious fact that, taking a long term of years, the average rainfall for each month differs but little, the rainfall of the so-called " dry months " being on the average but little less than that of the wet months. The greatly increased evaporation during the hot months, together with the demands of growing vegetation, etc., makes the rainfall seem much less than it really is and results in a greatly decreased run-off during those months. As the evaporation from ponds, brooks, reservoirs, etc., amounts to over 39 in. during an average year, it will be seen that the presence of large water surfaces in a watershed may have an important bearing on the amount of run-off to be expected from it. The accompanying diagram shows very clearly the relation between the average rainfall, evaporation, and run-off, as they occur in the Sudbury River watershed. (See Fig. 2.)

The distribution of the rainfall during the year has an important bearing on the amount of the yield or run-off. If the rainfall is largely during the season when the ground is frozen, a much larger run-off may be expected than if it occurred during the hot months, when the ground is dry and the evaporation rapid. This distribution and also the accumulated amount of rainfall to any date during the year can very graphically be shown by plotting each rainfall record on a print of the skeleton diagram shown on Plate II. The rainfall records of 1914 and 1915 are thus shown on Figs. 3 and 4.

From the above it will be seen that rainfall records can be made to serve a variety of practicable purposes, and that long time records obtained on or near the ground are most reliable and satisfactory.

The cost of an ordinary rain gage (not automatic or self-recording) is small, and its care and maintenance require only the atten-

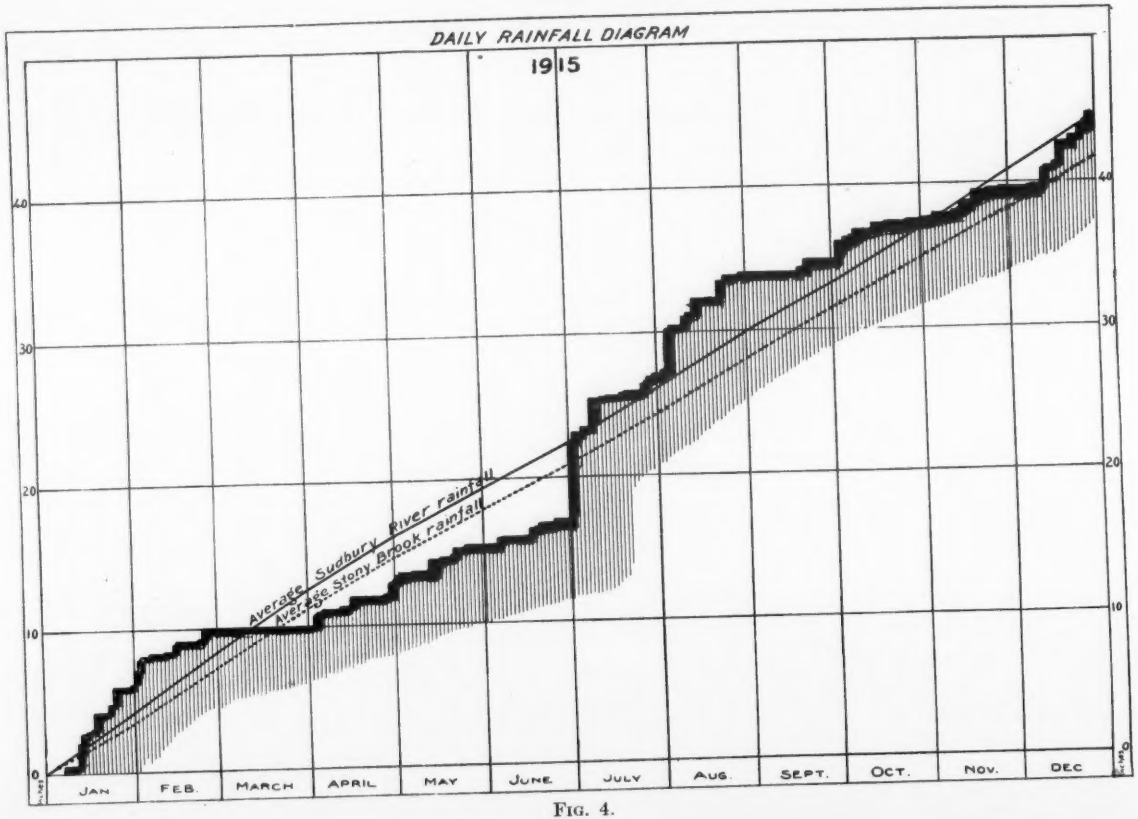

DAILY RAINFALL DIAGRAM
1915
40
30
20
10
0
Average Sudbury River rainfall
Average Stony Brook rainfall
JAN
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC

FIG. 4.

tion which can be given to it by some intelligent employee on the ground, or by some resident for a nominal sum. The United States Weather Bureau standard rain and snow gage is shown in Fig. 5.

If it is desired to obtain automatic records of the rainfall, a more complicated and expensive type of gage can be installed, and data obtained very useful in the study of many questions not

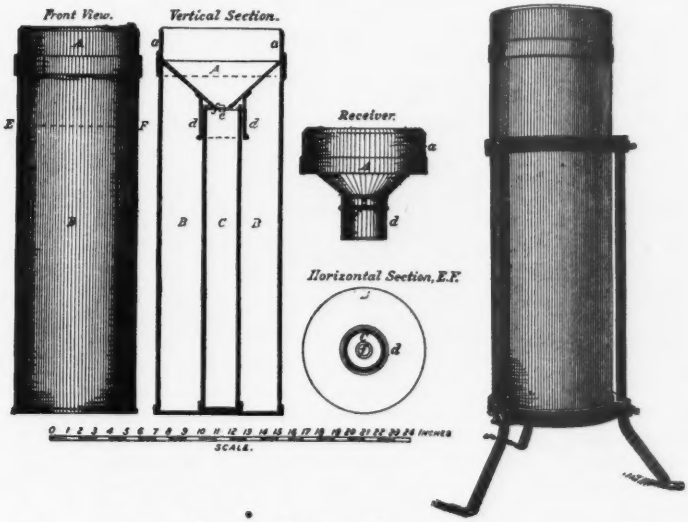


FIG. 5. RAIN AND SNOW GAGES.

covered by the mere *quantity* of rainfall, especially such as relate to the time at which the rainfall occurred and its intensity or rate per hour at any given time. These data are very interesting, and sometimes are exceedingly valuable as factors relating to the required strength and height of dams, length of spillways, size of culverts, damages caused by floods, overflows, washouts, raising or lowering of the water in storage reservoirs, and a great variety of other questions of a similar nature.

If a watershed is large, and the works established upon it are important and involve a large investment of capital, the establishment of an automatic rain gage is strongly recommended.

PROCEEDINGS.

December Meeting.

Hotel Brunswick, Boston, Mass.,
Wednesday, December 11, 1918.
2 P.M.

President Davis presiding.

The following members and guests were present:

Honorary Members.

E. C. Brooks. R. C. P. Coggeshall. R. J. Thomas. — 3.

Members.

D. L. Agnew.	Patrick Gear.	Leonard Metcalf.
S. A. Agnew.	F. J. Gifford.	H. S. Noyes.
L. M. Bancroft.	H. J. Goodale.	F. L. Northrop.
F. A. Barbour.	L. M. Hastings.	T. A. Peirce.
J. F. Barrett.	T. G. Hazard, Jr.	A. E. Pickup.
G. W. Batchelder.	D. A. Heffernan.	William Plattner.
C. S. Beaudry.	J. L. Howard.	H. W. Sanderson.
C. R. Bettes.	A. C. Howes.	C. M. Saville.
A. E. Blackmer.	J. A. Hoy.	A. L. Sawyer.
Bertram Brewer.	J. W. Kay.	C. W. Sherman.
F. L. Cole.	E. W. Kent.	G. H. Snell.
J. E. Conley.	Willard Kent.	W. F. Sullivan.
John Cullen.	S. E. Killam.	H. A. Symonds.
C. E. Davis.	G. A. King.	L. D. Thorpe.
A. O. Doane.	P. J. Lucey.	E. J. Titcomb.
L. R. Dunn.	Thomas McKenzie.	W. H. Vaughn.
E. D. Eldredge.	Hugh McLean	J. H. Walsh.
Frank Emerson.	H. V. Macksey.	R. S. Weston.
S. F. Ferguson.	J. H. Mendell.	I. S. Wood.
F. L. Fuller.	F. E. Merrill.	M. B. Wright — 60.

Associates.

Bond, H. L., Co., by F. M. Bates.
Builders Iron Foundry, by A. B. Coulters.
Chapman Valve Mfg. Co., by V. N. Bengle and M. E. Lynch.
Donaldson Iron Co., by C. F. Glavin.

Eddy Valve Co., by H. R. Prescott.
Engineering News-Record, by I. S. Holbrook.
Hersey Mfg. Co., by J. H. Smith.
Lead Lined Iron Pipe Co., by T. E. Dwyer.
Mueller, H., Mfg. Co., by C. J. G. Haas.
National Meter Co., by H. L. Weston.
Neptune Meter Co., by H. H. Kinsey.
Pittsburgh Meter Co., by J. W. Turner.
Rensselaer Valve Co., by I. A. Rowe and C. L. Brown.
Smith, A. P., Mfg. Co., by F. L. Northrop.
Thomson Meter Co., by E. M. Shedd.
Union Water Meter Co., H. W. Jacobs and D. K. Otis.
Water Works Equipment Co., by W. H. Van Winkle. — 20.

GUESTS.

MASSACHUSETTS.

Boston, G. C. Northrop.
Cambridge, Timothy W. Good.
Fall River, John W. Moran.
Groton, Arthur Wood.
Kingston, P. H. Delano.
Stoughton, E. E. Randell. — 6.

Singing: "America."

The Secretary read the following list of applicants for membership, approved by the Executive Committee:

Timothy W. Good, Cambridge, Mass., general superintendent Cambridge Water Department; Launcelot Paul Marshall, Rangoon, Burma, India, chief engineer, Rangoon Municipality; V. T. Givotovsky, Allston, Mass., student at M. I. T.; W. A. Keene, Turtle Creek, Pa., manager of Turtle Creek office of Pennsylvania Water Company; John W. Moran, Fall River, Mass., superintendent Fall River Water Department. — 5.

On motion of Mr. Edward N. Cogswell, the Secretary was instructed to cast the ballot of the Association in favor of the applicants named, and he having done so they were declared to be elected members of the Association.

PRESIDENT DAVIS. The Secretary has a letter, received from Mr. Robert E. Horton, which I would like to ask him to read, as it contains some very interesting suggestions on which I think the Association may care to act.

(Letter from Mr. Horton is read by the Secretary.)

NOVEMBER 18, 1918.

MR. WILLARD KENT, C.E.,
NARRAGANSETT PIER, R. I.

Dear Sir, — I would be pleased if you would call to the attention of the New England Water Works Association at its next regular meeting the advisability of collecting and publishing annually through the medium of a standing or special committee, results of stream flow and rainfall observations taken in connection with water-works systems throughout New England. The Society had laid an excellent foundation in the valuable papers on these subjects by Goodnough, relative to rainfall, and of the committee on yield of drainage areas relative to run-off. There are many rain gages maintained in conjunction with water-works systems in New England the results of which do not appear in the reports of the U. S. Weather Bureau. Probably most of these gages are subject to more frequent inspection and more personal care than the Weather Bureau has generally been able to give to rain gages maintained by its voluntary observers.

There are also many records of the yield of streams, especially small streams used for water-supply purposes, the results of which do not appear in the reports of the Geological Survey on stream gaging matters.

Rainfall data alone are valuable, and run-off data alone are valuable; but rainfall and run-off data where both are given for a particular drainage basin are much more valuable than either class of data alone. The records now being kept in conjunction with water-works systems in New England furnish many instances where these extremely valuable data may be obtained. Most of these records are kept under the direction of members of the New England Water Works Association. It would not involve a large amount of labor to collect these results year by year and publish them in one of the issues of the JOURNAL of the Association each year.

I respectfully request that this matter be called to the attention of the Association, and, if possible, an arrangement made to carry out this or some similar plan.

Yours very truly,

ROBERT E. HORTON.

PRESIDENT DAVIS. It seemed to the Executive Committee that that was a very fruitful suggestion and might result in bringing together a great deal of useful information. Have any of the members any thought in regard to the matter? Have you any comments or criticisms? The Executive Committee was inclined to appoint a committee, in a tentative way at least, to start this proposition and see if anything could be done, and if there is no objection I presume that that committee will be appointed and be asked to act.

MR. CHARLES W. SHERMAN. To remove any doubt, if there be any doubt, I move that the matter be referred to the Executive Committee with power.

(The motion was seconded.)

MR. LEONARD METCALF. Mr. President, might it not be well to couple with that also the statement that it is the sense of this meeting that it would be distinctly to the advantage of the Association to appoint such a committee? It seems to me that the suggestion by Mr. Horton is a very happy one, and the committee that may be appointed by the Executive Committee, and the Executive Committee itself, can determine after the material has been assembled how far it is well to publish it; in other words, whether it is worth publishing or not. But it certainly must be true, as Mr. Horton says, that there are many records available that have not been given publicity, that would broaden the field of useful information in such matters, and it is well that we should have it in hand.

PRESIDENT DAVIS. When it was discussed this morning it was thought that, to begin with at least, there could be published an index of what data there were, and that the data could be compiled to be furnished to every one when wanted. Possibly, later on, it might be published more completely. At least we could start it with an index of the data that were available, which could be had upon application. I assume that Mr. Sherman accepts Mr. Metcalf's suggestion. Are there any further comments?

MR. L. M. HASTINGS. I would like to say a word in regard to that. I want to second the motion most heartily, because I know from experience that there is a good deal of information in regard to rainfall and run-off — particularly rainfall, at any rate — amongst the water works of New England. And I know from experience that such data are very desirable to have. We have some data obtained here in New England, some in New York, and some in the more western part of the country. It is very essential, very useful, for every engineer who has to do with water works, either in the capacity of water supply or mill power, or in any other way where water is used either for power or domestic purposes, that the data to be used shall be obtained from localities near at hand. You can go to the western part of the country and of

course get rainfall data which would be of absolutely no value in this part of the country. If we start this movement to collate data in regard to rainfall and run-off, perhaps some of the superintendents in New England who have not established rain gages may be induced to set them up, if they felt that the data which they got would be not only useful to them but to others, and that they would have the use of the neighboring data. I might say that the establishment of a rain gage on a watershed is a comparatively inexpensive matter, and the maintenance of a suitable, accurate rain gage which gives you just simply the amount of rainfall, is very easily done, and it would be a simple matter for most superintendents to have rain gages set up on their watersheds, one or more in number, and the data in that way obtained. If this Association, with its large membership, would do that, I am sure that a mass of accurate and reliable data could be very readily obtained which would be extremely useful. It is a well-known fact that the longer a rain gage, for data of that kind, is kept up, the longer the period over which it extends, the more useful and reliable that data is. So that if we could set up twenty-five gages in different parts of New England and keep them for forty years, we would have a mass of information and data there that would be very useful indeed. I heartily support the motion and I hope it will prevail, and not only that we will get the records of what rain gages there are at present maintained but that new ones will be set up and maintained as well.

PRESIDENT DAVIS. There is one thing I might have said. As I recall it, Mr. Horton's letter would limit it to the New England states. I don't think that is at all necessary. I think that the data might be sent in from any of our members, wherever located, provided they obtained a record that was useful. What would you think about that, Mr. Hastings? It would not necessarily be limited to New England alone, would it?

MR. HASTINGS. No, sir; I think not. I think it would be interesting, although the farther away you get from your *locus* the less value it would have.

PRESIDENT DAVIS. But it would make our Association a headquarters for a great deal of information that would not be obtainable anywhere else. The more widespread geographically,

the more use the Association would be to the general public. I do not believe the New England Association ought to take any action which tends to identify its name with its membership; I believe it is country-wide.

A MEMBER. Along the line of what you have just suggested, I hope that you and the Association and the committee won't start out with the idea of publishing rainfall records all over the United States. When you consider the number of pamphlets issued yearly by the Geological Survey and the various branches of the Government, you can imagine where the Association would be if we published the rainfall records all over the United States.

PRESIDENT DAVIS. Well, I rather assumed that Mr. Horton's idea would be to bring together in New England that which was not published elsewhere, — the gages and records that are overlooked in the other publications. I agree with you that we can't have everything.

A MEMBER. I hope that the members of your committee will have an independent income and have nothing else to do.

PRESIDENT DAVIS. I do not believe the work of the committee need be too arduous. It perhaps may make one or two suggestions as to the form in which the data might be sent in. The work of the committee will grow as the reports come in. I do not believe the committee will be swamped with work.

(The question was put and carried.)

PAINTING STANDPIPES.

PRESIDENT DAVIS. The first paper this afternoon is "Painting Standpipes," by Mr. Charles W. Sherman. I understand Mr. Sherman's paper is not complete, and that he is not prepared to do more than make a few remarks to-day on the general subject, and there will be no discussion of the paper until a further date.

MR. CHARLES W. SHERMAN. I had not contemplated making even a general presentation to-day. Mr. Kent made out the program, and as I had promised this paper for the November meeting, when the Government work prevented me from preparing it, he doubtless assumed that it would be ready in December. Under

ordinary conditions that would probably be a reasonable assumption, but it did not work out so at this time.

Most of my data were accumulated two years ago, and I have not had an opportunity to look at them for nearly that length of time; consequently, I am not in a position to say much about the subject now. However, to satisfy the curiosity of some of the members who responded to my inquiry at that time, when a questionnaire was sent asking for information about their experiences with painting standpipes, and in order that they may know that it is not lost for all time, I will say that I made some preliminary steps towards tabulating the information, as far as it loaned itself to tabulation; but the net result is that, taking it by and large, the water-works men do not know very much about painting standpipes.

There are a few cases where they have very good records, but in a very surprisingly large number of cases the response came back something like this: " I have only been superintendent a short time, and my predecessor left no records, and I do not know what he put on the standpipe or when it was painted." When we get back to it, it means that all the money which water-works men have spent in painting standpipes has been in a more or less haphazard way, and the information we have been able to get has been almost nothing.

The data which I have, and which I hope to be able to present at a later meeting, are all that I have been able to compile from these returns, showing the kind of paint, as far as we can tell from the returns, — whether graphite or asphalt, or something else — and you know for yourselves what " graphite " or " asphalt " may mean,— it may mean anything. And as to the information relative to the treatment of the surface in preparation for painting, it is of a most meager character as a rule. And most of the other information runs along the same line. You can perhaps get some general information from the replies as to how often, under circumstances that have existed, standpipes have had to be painted. You will find one or two cases, perhaps three or four, where standpipes are twenty years or more old, and they say they have never seen the inside of them; they have never been opened since erected, and they " assume " they are in good condition. At

any rate, they have gotten by. But the superintendent who lets the standpipe go that way is taking a bigger chance than I would care to do, I think.

PRESIDENT DAVIS. We certainly do not want to discourage anybody who has come on here to take part in the discussion.

MR. H. A. MILLER. Mr. President, I am very much disappointed that we are not able to hear something about the paint, because, whenever I am up against painting anything, I always get sort of a nervous chill, as I do not know much about painting. I came here to-day feeling that I would get some information that would settle a great many questions, and I hope that Mr. Sherman will give us, at some future date, some information on painting standpipes. I believe that, at the present time, it is one of the things regarding which we have very little information.

PRESIDENT DAVIS. Then we will pass to the next paper, — "Small Pumping Engines," by Mr. Symonds.

Mr. Symonds then presented his paper, which was discussed by President Davis and Messrs. Frank L. Fuller, Samuel A. Agnew, J. Harold Hayes, F. H. Hayes, Bertram Brewer, A. O. Doane, Reeves J. Newsom, T. G. Hazard, Jr., C. W. Fulton, and Leonard Metcalf.

Owing to the lateness of the hour, the further consideration of the report of the committee on frozen water services was postponed until some subsequent meeting.

Adjourned.

ANNUAL MEETING.

HOTEL BRUNSWICK, BOSTON,
January 8, 1919.

The President, Carleton E. Davis, in the chair.

The following-named members and guests were present:

HONORARY MEMBERS.

E. C. Brooks. R. C. P. Coggeshall. F. E. Hall.
F. P. Stearns. — 4.

MEMBERS.

S. A. Agnew.
L. M. Bancroft.
W. T. Barnes.
H. K. Barrows.
G. W. Batchelder.
A. E. Blackmer.
J. W. Blackmer.
George Bowers.
Bertram Brewer.
H. B. Burley.
J. C. Chase.
F. L. Cole.
W. R. Conard.
John Cullen.
F. A. Darling.
C. E. Davis.
J. H. Dillon.
J. M. Diven.
A. O. Doane.
J. N. Ferguson.
S. F. Ferguson.
Patrick Gear.
H. T. Gidley.
H. J. Goodale.
F. W. Gow.
F. M. Griswold.
T. G. Hazard, Jr.
Allen Hazen.
D. A. Heffernan.
J. L. Howard.
W. F. Howland.
J. A. Hoy.
J. W. Kay.
E. W. Kent.
Willard Kent.
J. A. Kienle.
S. E. Killam.
H. O. Lacount.
T. E. Lally.
G. H. Leland.
P. J. Lucey.
D. B. McCarthy.
F. A. McInnes.
W. A. MacKenzie.
H. V. Macksey.
F. A. Marston.
J. H. Mendell.
C. W. Mills.
H. A. Miller.
F. L. Northrop.
A. E. Pickup.
L. C. Robinson.
P. R. Sanders.
J. W. Smith.
G. H. Snell.
H. A. Symonds.
A. H. Tillson.
D. N. Tower.
W. E. Whittaker.
H. F. P. Wilkins.
F. E. Winsor. — 61.

ASSOCIATES.

Bond, H. L. Co., by F. M. Bates and F. M. Matthies.
BuildersIron Foundry, by A. B. Coulters.
Byers, A. M., Co., by H. F. Fiske.
Central Foundry Co., by R. W. Conard.
Donaldson Iron Co., by C. F. Glavin.
Eddy Valve Co., by H. R. Prescott.
Edson Mfg. Co., by H. L. B. Watson.
Fire and Water Engineering, by C. B. Hayward.
Hayes Pump and Machinery Co., by F. H. Hayes.
Hersey Mfg. Co., by J. H. Smith.
Lead Lined Iron Pipe Co., by T. E. Dwyer.
Ludlow Valve Mfg. Co., by A. R. Taylor.
National Meter Co., by J. G. Lufkin.
National Water Main Cleaning Co., by B. B. Hodgman.
Neptune Meter Co., by H. H. Kinsey.
A. P. Smith Mfg. Co., by F. L. Northrop.
Thomson Meter Company, by E. M. Shedd.
Union Water Meter Company, by H. W. Jacobs.
United Brass Mfg. Company, by G. A. Caldwell and W. N. Fairfield.
Wood & Company, R. D., by E. J. Lame.
Worthington Pump and Machinery Corp., by Samuel Harrison and W. F. Bird. — 24.

GUESTS.

NEW HAMPSHIRE.
Manchester, Frank Dill and George Woolner.

MASSACHUSETTS.
Cohasset, L. T. Litchfield.
Holyoke, Frank M. Livingstone.

NEW YORK.
New York City, S. Willard Jacobs and G. C. Northrop.
Woodhaven, James Cochran. — 7.

At the request of President Davis, after calling the meeting to order, all present rose and remained in most impressive silence with bowed heads, as a tribute to the memory of ex-President Roosevelt. Then the Secretary read the following resolution, reported by the Executive Committee:

"The New England Water Works Association hereby records its deep sense of loss in the death of Theodore Roosevelt, former President of the United States and a typical American. His strong and vigorous manhood and extraordinary range of activities brought him frequently in touch with the interests of this Association. As individuals we are grieved, and as an organization we feel his passing keenly."

On motion of Mr. James H. Mendell, it was voted that the resolution be adopted and published in the JOURNAL.

The Schumaker-Santry Company, Boston, power-plant equipment engineers, was elected to associate membership.

The Secretary, Mr. Willard Kent, submitted the following report:

REPORT OF THE SECRETARY.

JANUARY 1, 1919.

Mr. President and Gentlemen of the New England Water Works Association, — The Secretary submits herewith the following report of the changes in membership during the past year, and the general condition of the Association.

The present membership is 905, constituted as follows: 13 Honorary, 815 Active, and 77 Associate Members, there being a net loss for the year of 97. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1918.	Honorary Members.....	14	
	Died.....	1	
		—	13

January 1, 1918.	Total Members		901		
	Withdrawals:				
	Resigned	54			
	Dropped	42			
	Died	16			
		—	112		
			—	789	
	Initiations:				
	February	4			
	June	3			
	September	5			
	November	4			
	December	4			
		—	20		
			—	20	
	Reinstated:				
	Member dropped in 1913	1			
	Members dropped in 1917	4			
		—	5		
	Elected 1917, qualified 1918		1		
			—	6	
				—	815
January 1, 1918.	Total Associates		87		
	Withdrawals:				
	Resigned	7			
	Dropped	4			
		—	11		
			—	76	
	Elected 1917, qualified 1918			1	
				—	77
January 1, 1919.	Total membership				905
January 1, 1918.	Total membership				1 002
	Net loss				97

The Secretary has received and paid to the Treasurer, $7 941.51.

Of this amount, the

Receipts for initiation fees were			$97.00
From dues of members	$3 314.13		
From dues of members, fractional	15.00		
From dues of members, past	15.25		
		$3 344.38	
From dues of Associates	$1 620.00		
From dues of Associates, fractional	1.25		
		1 621.25	
Total from dues			4 965.63

From advertising	$1 815.00
From subscriptions	244.50
From JOURNALS	63.51
From sundries	755.87
Total as above	$7 941.51

There is due the Association at this date:

For advertising	$134.02

The outstanding bills against the Association amount to $1 007.36.

Respectfully submitted,

WILLARD KENT, *Secretary.*

REPORT OF THE TREASURER.

Mr. Lewis M. Bancroft, Treasurer, submitted the following report:

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$198.22
Initiation fees	$97.00	
Dues	4 965.63	
Total received from members		5 062.63
JOURNAL:		
Advertisements	$1 815.00	
Subscriptions	244.50	
Sale of JOURNALS	63.51	
Sale of reprints	127.87	
Sale of cuts	4.62	
Total received from JOURNAL		2 255.50
Miscellaneous Receipts:		
Sale of "Pipe Specifications"	$5.40	
Dinners	567.00	
Certificates of membership	6.00	
Buttons	1.50	
Meter rate slips	3.62	
June excursion	26.02	
Miscellaneous	7.44	
Total miscellaneous receipts		616.98
Total receipts		$8 133.33

LEWIS M. BANCROFT, *Treasurer.*
In account with the New England Water Works Association.

RECEIPTS.			EXPENDITURES.		
1918.					
Jan. 1.	Balance on hand	$3 104.59	Bills paid		$8 280.89
	Received of Willard Kent, Secretary,	7 941.51	BALANCE ON HAND.		
	Interest on bonds and deposits	191.82	People's Savings Bank	$2 000.00	
			Mechanics Savings Bank	422.00	
			First National Bank	93.06	
			Liberty Trust Co.	441.97	
					2 957.03
		$11 237.92			$11 237.92

ASSETS AND LIABILITIES.

ASSETS.		LIABILITIES.	
Cash balance in banks	$2 957.03	Accounts payable	$0.00
Bonds Nos. 2642 and 2644 Lake Shore & Mich. Southern R. R., due May 1, 1931. Book value, $1 815.00. Market value	1 760.00	Surplus	4 851.05
Accounts receivable:			
Advertising	134.02		
	$4 851.05		$4,851.05

READING, January 6, 1919.

LEWIS M. BANCROFT, *Treasurer.*

Expenditures.

JOURNAL:			
Advertising agent's commission		$177.15	
Plates		45.23	
Printing		2 929.62	
Editor's salary		300.00	
Editor's expense		31.36	
Reporting		224.70	
Reprints		372.25	
Envelopes and postage		22.70	
			$4 103.01
Office:			
Secretary's salary		$200.00	
Secretary's expense		24.75	
Assistant to Secretary		1 170.00	
Assistant to Secretary, expenses		139.57	
Rent		550.00	
Printing, stationery, and postage		295.17	
			2 379.49
Meetings and Committees:			
Reporting		$28.50	
Stereopticon		94.70	
Dinners	$730.70		
Cigars	10.00		
Music	16.00		
		756.70	
Printing, stationery, and postage		328.46	
Badges		36.34	
Rent		45.00	
			1 289.70
Treasurer's salary and bond			67.50
Certificates of membership			3.60
Water-waste posters			275.00
Dues of members in service			136.00
Flowers			18.00
Income tax			8.59
			$8 280.89

Report of Auditing Committee.

Mr. Bertram Brewer presented the following report of the Auditors:

Boston, Mass., January 8, 1919.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers. Respectfully submitted,

GEORGE A. CARPENTER,
EDWIN L. PRIDE,
BERTRAM BREWER,
Auditing Committee.

On motion it was voted that the reports of the Secretary, Treasurer, and Auditors as read be accepted.

Report of the Editor.

(Not read before Association.)

January 15, 1919.

To the New England Water Works Association, — I present the following report for Journal of the New England Water Works Association for the year 1918

The accompanying tabulated statements show in detail amount of material in the Journal.

Size of Volume. — The volume contains 557 pages, a reduction of 251 pages from that of 1917, which was the largest ever published.

Reprints. — The usual fifty reprints of papers have been furnished to authors without charge.

Circulation. — The present circulation of the Journal is:

Members, all grades	905
Subscribers	84
Exchange	21
Total	1 010

a decrease of 102 from the preceding year. Journals have been sent to all advertisers.

Advertisements. — There has been an average of 28 pages of paid advertisements with an income of $1 972.50, a slight increase over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $5.50 have been sold. The net gain up to a year ago had been $316.65, so that the total net gain from this source to date is $322.15. There are 139 copies of specifications on hand, $13.90 worth if sold at retail.

The Association has a credit of $12.55 at the Boston Post Office, being the balance of money deposited for payment of postage upon JOURNAL at pound rates. The following tables are for Volume XXXII, not for the calendar year, and receipts and expenditures show total charges and accounts payable with no reference to amounts actually received or disbursed.

TABLE 1.

STATEMENT OF MATERIAL IN VOLUME XXXII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1918.

Number.	Date.	Pages of								Total Cuts.
		Papers.	Proceedings.	Total Text.	Index.	Advertisements.	Cover and Contents.	Inset Plates.	Total.	
1	March	102	18	120	.	32	4	.	156	17
2	June	61	7	68	.	32	4	1	105	1
3	September	91	18	109	.	33	4	1	147	1
4	December	92	8	101	5	32	4	7	149	27
	Total	346	51	398	5	129	16	9	557	46

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXXII, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1918.

Receipts.		*Expenditures.*	
Advertisement	$1 972.50	Printing JOURNAL and mailing	$1 847.88
Sale of JOURNALS	63.51	Printing illustrations	304.00
Sale of reprints	127.87	Preparing illustrations	120.66
Sale of cuts	4.62	Editor's salary	300.00
Subscriptions	252.00	Editor's incidentals	6.36
	$2 420.50	Advertising agent's salary and commission	118.40
Net cost of JOURNAL	694.50	Reporting	224.70
		Reprints	193.00
	$3 115.00		$3 115.00

TABLE 3.

COMPARISON BETWEEN VOLUMES XXI TO XXX, INCLUSIVE (OMITTING VOLUME XXXI), NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXII. 1908.	Vol. XXIII. 1909.	Vol. XXIV. 1910.	Vol. XXV. 1911.	Vol. XXVI. 1912.	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.
Average edition (copies printed)	1 000	1 000	1 150	1 000	1 000	1 000	1 050	1 325	1 500	1 388
Average membership	699	710	732	752	740	745	803	904	1 002	954
Circulation at end of year	780	802	827	840	826	858	951	1 079	1 155	1 010
Pages of text	500	459	643	475	401	554	564	596	538	398
Pages of text per 1 000 members	715	646	880	632	542	746	702	659	538	417
Total pages, all kinds	681	627	808	654	567	733	719	776	707	557
Total pages per 1 000 members	976	884	1 090	870	766	984	895	859	707	584
GROSS COST:										
Total	$2 733.61	$3 111.15	$3 490.81	$2 625.87	$2 476.55	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00
Per page	4.01	4.97	4.32	4.02	4.37	4.89	4.65	5.47	4.79	5.59
Per member	3.91	4.39	4.78	3.50	3.35	4.81	4.17	4.68	3.38	3.26
Per member per 1 000 pages	5.88	7.00	5.90	4.09	5.90	6.46	5.80	6.02	4.79	5.85
Per member per 1 000 pages text	8.02	9.56	7.44	7.36	8.35	8.68	7.39	7.85	6.30	8.19
NET COST:										
Total	$131.06	$789.98	$1 334.06	$352.82	$98.81	$1 322.90	$1 155.33	$2 091.09	$1 171.98	$694.50
Per page	.19	1.26	1.65	.54	.17	1.80	1.61	2.70	1.65	1.25
Per member	.19	1.11	1.82	.47	.13	1.78	1.44	2.32	1.17	.73
Per member per 1 000 pages	.28	1.78	2.25	.55	.23	2.42	2.00	2.98	1.65	1.31
Per member per 1 000 pages text	.39	2.43	2.83	.98	.33	2.38	2.55	3.88	2.17	1.83

Reports of Committees.

Standard Specifications for Cast-Iron Pipe.

President Davis. Is there any report from Mr. McInnes or any member of the Committee on Standard Specifications for Cast-Iron Pipe?

Mr. Conard. In the absence of Mr. McInnes, the committee can only say that, due to the war conditions, there is nothing but progress to report.

Standard Specifications for Fire Hydrants.

Mr. H. O. Lacount. At the meeting in April, 1914, which was a special meeting, the hydrant specifications were adopted in part, but certain items, regarding which there were questions, were referred back to the committee for further consideration. I wrote to the manufacturers regarding one item, which was the matter of the friction loss, to obtain from them data regarding their own hydrants. I did not get any information from them at that time, and as a matter of fact I have not yet, but for reasons which will appear I did not follow up my first letter, so that we won't lay too much blame at the door of the manufacturers, because they have been very busy. Then, a little later, the war broke out and the manufacturers generally, including the hydrant manufacturers, were increasingly busy from that time practically to the present, and it seemed to be rather inadvisable to bring up the matter of revision of the specifications, which might lead to a demand for different construction or design from what they were putting out at the time. Consequently the matter was allowed to rest.

But since the armistice has been signed, and since the Secretary said that now was the time to go at it again, I just want to say, as a matter of progress, that the particular points which were referred back to the committee are now again before the committee and that we are very hopeful that in due time we may have something specific to offer again for your consideration. It has, however, seemed, at least to the chairman, — and I have not yet heard from the other members of the committee, — that it

would be advisable, in view of the importance of these items which are to be considered, that the suggestions of the committee be bulletined to the members of the Association, so that the members may see in advance exactly what is proposed and be better prepared for discussion when the matter is finally before the Association in an open meeting. That we shall probably do, and, therefore, you will be advised in advance when the matter is to come before you again, with the idea that we may then finish the work which was begun some time ago. This I would suggest, therefore, as a progress report.

PRESIDENT DAVIS. Is there any discussion of this progress report?

MR. J. M. DIVEN. Do I understand that the committee has a printed report on these three items which are under discussion, which will be published?

MR. LACOUNT. We haven't the report yet completed. There are certain suggestions which are now before the committee. The committee has not had a meeting, and therefore the members are not even prepared to announce their own ideas on these points. The thought was that, rather than bring in a report which would not have advanced consideration, it was well not only to take the matter up with the manufacturers, which we naturally would do anyway, before sending out our report, but also to bulletin it to the Association members so that they might have an opportunity to consider it in advance of final discussion.

On motion it was voted that the report be accepted and placed on file as a progress report.

Statistics of Water Purification Plants.

(George C. Whipple, Chairman.)

The Secretary read a letter from Mr. Whipple, in which he said:

"I am sorry to say that we are not yet able to report, as the war has prevented all work of the committee during the past year. Will you be good enough to consider this as a request from the committee for a further extension of time."

PRESIDENT DAVIS. I take it that there is no objection, and the request will be granted and the committee continued.

Leakage of Pipe Joints.

(F. A. Barbour, Chairman.)

PRESIDENT DAVIS. Mr. Barbour is not here, but the Secretary has a letter from him which he will read.

The Secretary read the following letter:

NEW ENGLAND WATER WORKS ASSOCIATION,
WILLARD KENT, *Secretary:*

Dear Sir, — Replying to yours of December 18, in reference to report of the Committee on Leakage of Pipe Joints, I have to inform you that during the past year no work has been done by this committee, and no report will therefore be available for the annual meeting of the Association. Future progress in the investigations of this committee depend on experimental work, involving the employment of mechanics and laborers, and conditions during the past year have not been favorable for such an undertaking.

Yours very truly,

F. A. BARBOUR.

PRESIDENT DAVIS. I think Mr. Barbour ought to have some new associates on his committee. I happen to be one member of the committee, and I know that I have done nothing except make promises which have not been fulfilled. Some of those promises were in connection with the mechanical work which Mr. Barbour suggested. He outlined a very interesting series of experiments, and I think some of them may go forward within the next few months.

Standard Specifications for Meters.

(Charles W. Sherman, Chairman.)

MR. SHERMAN. The committee has not been able to hold a meeting during the year, but there has been some correspondence between the members, and some data have been accumulated in written form, so that we can report progress in a technical sense, although the amount of progress has not been very great. We hope with the cessation of war-time activities we shall all have a little more time to give to professional subjects, and that we shall be able to accomplish something more tangible during the coming year.

Revenue from Fire Services.

(W. C. Hawley, Chairman.)

The Secretary read the following letter:

DECEMBER 20, 1918.

MR. WILLARD KENT, *Secretary*,
NEW ENGLAND WATER WORKS ASSOCIATION,
715 TREMONT TEMPLE, BOSTON, MASS.

Dear Sir, — Replying to yours of the 18th inst., would say that the Committee on Revenue from Fire Services has not had a meeting owing to conditions brought about by the war and the absence of Mr. E. V. French in France. I am very sure, however, that the individual members of the committee have the matter in mind, and that when we are able to meet it will be found that substantial progress has been made, and we shall hope to be able to make a report to the next convention.

The matter of rates for private fire protection is coming more and more to the attention of the public service commissions and is being studied by them, and I think that we may hope for some decisions which will be helpful in the near future. In my own case I know that I have been having some experience within the last two years on this subject which has led me to change my mind quite materially on the question of how and what sort of charges should be made for private fire protection.

Yours very truly,

W. C. HAWLEY.

PRESIDENT DAVIS. I suppose the committee will be continued.

Frozen Service Pipes.

(Frank J. Gifford, Chairman.)

PRESIDENT DAVIS. There ought to be considerable discussion of this, because it has been up once or twice and is unfinished business. Mr. Gifford is not here, but Mr. Lally is present.

MR. THOMAS E. LALLY. The committee has nothing further to report at the present time. The matter has been dragging along ever since the September meeting, and we have hoped that somebody would get up and start something, but nobody seems to care to do it. If any of the members here would like to have any information which the committee can give, we would be glad to give it.

MR. D. A. HEFFERNAN. I would like to have this matter go over until the next meeting and have it advertised for that meeting, because there are not many superintendents here to-day. If it can be advertised as one of the matters for discussion at the February meeting, then perhaps the superintendents will come in and tell us their experience during the last winter.

PRESIDENT DAVIS. I think the committee ought not to be disappointed because of the lack of discussion of their report; in fact, I think it is a compliment to them, and it is because their treatment of the subject was so full and complete and their investigations so comprehensive that I believe the members feel that by going to the report they can find almost any question answered. I know that has been my thought on the subject, and I presume it has been that of a great many, that the committee had covered the subject so comprehensively there could not much more be said.

Priorities.

(Willard Kent, Chairman.)

MR. WILLARD KENT. Your Committee on Priorities, appointed June 19, 1918, to protest in behalf of the Association against the classification of the manufacture of meters and other waterworks supplies as non-essential industries, find themselves unable to make even a progress report. President Davis of our Association had previously been appointed on a committee from the American Water Works Association on the same subject, and our committee was appointed to work in conjunction with them.

As the result of his initiative he advised us that "it is absolutely useless to interview the Priorities Board on any general matter. They will take up specific cases, but absolutely decline to interest themselves in general matters. Any attempt to secure action along general lines is impracticable."

The New England Preferred List of Industries and Plants, issued September 3, 1918, placed public utilities in Class 2, a much more liberal classification than those which had preceded it.

As you know, the committee and the Association suffered a great loss in the death of Mr. William F. Woodburn, who with

Mr. Seth D. Higley had recently been added to the committee. A letter written by Mr. Woodburn three days before his death emphasizes his deep interest in the Association, of which those who had the pleasure of his intimate acquaintance are so well aware. It is as follows:

BOSTON, MASS., September 12, 1918.

MR. WILLARD KENT,
NARRAGANSETT PIER, R. I.

Dear Mr. Kent, — I understand that I have been appointed on your Priorities Committee and am disregarding the formality of waiting for notification of this appointment to write you that if it is the intention that this committee get results, I am with you, as what we accomplish will be a great benefit not only in New England, but all over the United States of America.

It will mean *quick, forceful* action, with lots of hard work, and the backing of the Association on any action the committee may consider wise; but result will be worth it.

Kindly advise me what has been done by the committee to date.

Sincerely,

WM. F. WOODBURN.

201 DEVONSHIRE STREET,
BOSTON.

I am pleased to say that it is the belief of your committee that the exigencies which called for its appointment are past, and that there is now no good reason for its continuance.

WILLARD KENT, HIRAM A. MILLER,
A. E. MARTIN, SETH D. HIGLEY,
WM. F. WOODBURN,
(Deceased.)

Committee on Priorities.

PRESIDENT DAVIS. I take it that a motion to accept the report and discharge the committee will be in order.

On motion it was voted that the report be accepted and the committee discharged.

THE DEXTER BRACKETT MEMORIAL MEDAL.

PRESIDENT DAVIS. The award of the Dexter Brackett medal is the next matter of business. The Secretary will announce the action of the Executive Committee.

THE SECRETARY. The Executive Committee at its meeting

to-day voted to award the Dexter Brackett memorial medal for the year 1917 to Mr. Albert L. Sawyer, water registrar, Haverhill, Mass., for his paper entitled, "Some Advantages of Classified Cash Books."

PRESIDENT DAVIS. Mr. Sawyer is not here this afternoon, and it was not the intention to make the presentation at this time, but merely to indicate the action of the committee. I presume Mr. Sawyer will be here at the February meeting, and we will make the presentation then. I want to express my gratification that the award has been made to Mr. Sawyer, and that it has been made for a paper of this particular character.

(Later in the afternoon the newly elected President, Mr. Killam, announced that the Executive Committee had appointed as a committee to award the Dexter Brackett medal for the year 1918, William T. Barnes, William F. Sullivan, George W. Batchelder. The committee will report before August 1, 1919.)

ADDRESS BY THE RETIRING PRESIDENT.

PRESIDENT DAVIS. In entering on the period of reconstruction a glance backward over the era of war is not unnatural. None of us proposes to linger unduly or be diverted from the immediate problems of the future, but a reasonable view backwards may be an inspiration for what is ahead.

Water-works officials may feel legitimate pride that the utilities under their direction responded generally to the public necessities in a satisfactory way. Probably no other function, essential for the prosecution of the war, suffered fewer breakdowns and caused less concern to the consumer than did the water supplies, notwithstanding that water works, equally with other public-function activities, were handicapped by the general difficulties of the situation. These results were the operator's contribution to the general cause, and the outcome testifies to the fundamental soundness of the water-works plants of the country.

The period of reconstruction — physical, mental, moral, and financial — now comes. We have all drawn on our capital resources, whether invested in plant which has deteriorated by accel-

erated depreciation, or held in some other form. It is universally held that fundamental changes are at hand, and various opinions as to what the future will develop may be had for the asking. Definite predictions at this time are largely valueless; but we all know that when materials are in a state of flux, the opportunity of the molder is at hand. Out of the present situation will come whatever those who are able to form and direct may desire.

Our Association has passed through the war without material change or without suffering serious loss in numbers or resources. We have had no opportunity to perform conspicuous public service as a body, but through individual members and through the uniquely essential works which those members represent, the Association has rendered indispensable help.

It is not out of place to repeat the statement previously made, that the country was notably prepared for war in sanitary science and military public health activities in which this Association has performed sound pioneer work.

Reconstruction will affect this Association as a body, as well as the utilities which its members control. As a body of men we definitely control the future of our own Association and can shape its course as we choose. In the future, as in the past, the New England Water Works Association will be guided by men of wide vision who will lead and not follow, and we may look forward with confidence in the certainty that this Association will maintain its preëminent position. But changes are inevitable, and the Association will not wait for outside influences to take the initiative; rather it will shape its course in such a way as to be in the forefront of new thought and activities.

Suggestions and recommendations will be premature, but thoughts expressed out loud may not be inopportune. Our Association has a unique position in reasonable centralization of membership, frequent meetings, and permanent headquarters. Greater advantage will doubtless be taken of this situation, and the headquarters organization developed in a way to render larger return to the membership.

We have the opportunity of assuming a commanding position as the recognized center of water-works data and information. The Association will grow according to the service it renders.

There is an opening for a new field of usefulness in the development of the headquarters force so that any person, anywhere, desiring information on water-works subjects will think naturally of the New England Water Works Association as the source to which to apply. Such service would bring returns in increased membership, wider circulation of the JOURNAL, and greater advertising value for its pages.

The Association has always been notable for the freedom and frankness of discussion at its meetings, such freedom being caused by the knowledge that the Editor is a judicious reporter. The JOURNAL has the reputation of being the most sound and practical publication of its kind, truly reflecting the nature of the organization.

Perhaps the younger members are not heard from as frequently as desirable, and the well-worn formula that the young members must be encouraged is often heard. There is a natural gravitation of one age to a like age, and it may be that there has been an undue representation of the members of maturer years in the management of the Association, who may lack the necessary acquaintance among the younger men to bring out all their possibilities. I feel sure I voice the unanimous desire of all when I commend to all members, younger or older, the overcoming of any reluctance to offer whatever they have in mind at any time, with the assurance that it will be heartily welcomed. The Association follows the advice of Saint Paul to the Thessalonians, to try all things and retain that which is good.

The old-fashioned experience meetings are typical of the spirit of this Association. They were good for the soul and good for the mind, and personally I hope it will be found proper to develop and increase their number. They have been the means of placing at the disposal of the general water-works practitioner a vast fund of invaluable information concerning ways and means, and at the same time they have furnished a wonderful safety valve for pent-up feelings. True, there is an outlet for such feelings in conversation with fellow-members during the social periods incident to the meetings, but not all members can attend the meetings, and even reading about the other man's troubles is often a great relief.

Possibly the future may develop periodical meetings conducted by the associates, — meetings at which the present practice will be reversed and the associates talk while the members listen. It may be that the associates are now obtaining an undue advantage in listening to the views of the members, pro and con, without being obliged to commit themselves to any line of action. On the other hand, perhaps the members are not availing themselves of an opportunity to hear a frank discussion between the various makers of the articles in everyday use by the waterworks operator. Nothing could be more enlightening than a free discussion between makers of competitive goods, and doubtless such discussions could be brought about without detriment to any and with profit to all, apart from the features that may savor of competition. There are likewise vast funds of useful information in regard to fundamentals at the command of the associates which could profitably be placed at the disposal of the Association.

This same principle might be carried further with advantage, and associates be given membership on committees investigating subjects in which the associates are vitally interested. Such a procedure would give the opportunity for a minority report, if such should be necessary, and thereby tend to the more complete enlightenment of the Association on all phases of any particular subject.

One change which has already been effected by the war, and at the instance of this country, is open diplomacy and the adoption of perfect frankness in discussion. In following these lines the Association will doubtless reconstruct the present rather indefinite financial status of the associates. From dues and through advertising, the Association derives about one half of its income from the associates, and for the conventions accepts or solicits contributions for entertainments and hospitality. This is not done solely as a matter-of-fact business transaction, nor do the associates make such contributions solely because of their personal regard and esteem for the members. The business factor is tempered by the fact that the association furnishes a medium through which personal relations are developed to the mutual advantage of both parties having business to transact with each

other. This is the case, and the situation should be frankly recognized and put on a definitely understood basis.

A notable recognition of the wide range of activities embraced within the membership of this Association is the award of the Brackett memorial for a paper devoted to accounting. The water-works operator has been too often classified as a specialist on pumps, pipes, reservoirs, or some similar matter, while in fact he is responsible for not only the operation of highly specialized machinery but he is further charged with the conduct of large business interests. By its own action, the Association now lays claim to this larger sphere of operations, and asserts the proper standing of its members in the community.

The annual convention in 1918 was on a strictly war-time basis, without special entertainment and without the customary exhibits. An innovation in the way of poster advertising urging the reduction of waste as a means of saving coal was an accompaniment of the convention which attracted considerable attention. The idea of saving coal by this method was taken up and expanded by the national Fuel Administration.

I have purposely refrained from any extended or detailed enumeration of events of the past year for the past at this period is behind us in an entirely new sense, and we are at the beginning of an entirely new era to which we are looking ahead with confidence.

Election of Officers.

Mr. Thomas E. Lally presented the following report of the tellers appointed to canvass ballots for election of officers:

Whole number of ballots	246
Blanks	

President.

Samuel E. Killam	244

Vice-President.

Henry V. Macksey	240
Charles W. Sherman	242
Percy R. Sanders	241
Frank A. Barbour	239

Thomas McKenzie	241
James H. Mendell	240
Secretary.	
Willard Kent	242
Treasurer.	
Lewis M. Bancroft	242
Editor.	
Henry A. Symonds	244
Advertising Agent.	
Henry A. Symonds	241
Additional Members Executive Committee.	
Frank J. Gifford	240
A. R. Hathaway	240
Patrick Gear	236
Scattering	1
Finance Committee.	
George A. Carpenter	240
Edwin L. Pride	239
Frank A. Marston	238

(Signed) THOMAS E. LALLY, *Chairman.*
W. E. WHITTAKER.

President Davis thereupon declared the following to have been elected officers for the ensuing year:

President, Samuel E. Killam.

Vice-Presidents: Henry V. Macksey, Charles W. Sherman, Percy R. Sanders, Frank A. Barbour, Thomas McKenzie, James H. Mandell.

Secretary, Willard Kent.

Treasurer, Lewis M. Bancroft.

Editor, Henry A. Symonds.

Advertising Agent, Henry A. Symonds.

Additional Members Executive Committee: Frank J. Gifford, A. R. Hathaway, Patrick Gear.

Finance Committee: George A. Carpenter, Edwin L. Pride, Frank A. Marston.

President Davis then called the new President to the chair.

Address by President Killam.

Mr. President and Fellow-Members of the New England Water Works Association,—I am honored and I greatly appreciate the honor of being elected President of this Association.

In sharing the honors and the responsibilities of the management of the Association with its newly elected officers permit me to request that the same good-fellowship and hearty coöperation, for which this organization is noted, be continued throughout the coming year. Individual efforts are commendable, but without the constant coöperation of the membership we cannot reach the effective and successful end that is desired.

Now, with the record of the great war behind us — a record of which we all are justly proud — let us welcome back our members and face the reconstruction work with renewed vigor. We each have a duty to perform, and one which as managers, superintendents, engineers, and manufacturers we owe not only to ourselves and to the communities we serve but to the general public. Therefore let us meet this duty squarely, with a firm and steadfast resolution to overcome the delays that have been inevitable during the past year. Well have your water supplies been guarded, and great credit is due to the measures taken to preserve and safeguard the public health during the past troublous months; and may the lessons learned be given, in due time, to the fraternity, so that mutual benefit may be derived from your experiences in planning reconstruction and extension of the present works or the laying out of new supplies.

To the active members I would say that the future of the Association is in your hands. It is your duty to continue this organization as the leading power which it has always maintained in the water-works fraternity. Let us therefore work together to carry out those high ideals that are ours by inheritance, lest some similar society replace our standard by actual achievements. I ask the members, irrespective of profession, to volunteer for active service in order that our higher ideals may be put into action. If volunteers fail us it may be necessary to resort to selective draft in order to secure papers and membership on committees.

To the members that have been long in service I extend a most cordial greeting, and beg you to tarry with us that we may have the benefit of your long and varied experiences. The Association needs your counsel as much to-day as it did years long ago, so that the high standard which you have set may be maintained in the future.

May the associate members, who have always shown the highest regard for this body, continue to exercise the same influence for building up this Society in the future as in the past, so that the founders — who builded better than they knew — may look with pride on the good-fellowship and hearty coöperation which has always existed between the active and associate membership.

I congratulate you on the personnel of the officers who have been elected to serve with me during the coming year. In every live organization there will always be differences of opinion as to management. A free and frank discussion of such differences will be very beneficial in administrating the affairs of the Association. Let us enter upon our duties with open minds and with firm determination to carry on the work for higher ideals, better service, and in the best interests of the New England Water Works Association.

Is there anything further to be brought before the Association at this time?

Mr. Henry A. Symonds. Mr. President, at the beginning of a new year it is proper that we should look into all Association matters, and if possible inaugurate new and improved methods for the coming twelve months.

With this in view, I wish to call attention of the Association to what seems to me to be an obligation of the members of this Association towards the advertisers in the Journal, which you have been kind enough to place in my hands for another year.

It seems evident that for all firms and individuals furnishing supplies, or doing business in any way relative to water works, there is no medium in this section of the country which fills the needs of a good advertising medium equal to the New England Water Works Association Journal.

There have been occasional complaints that the advertising by the associate members was rather to help along the Association than because of the value they placed upon the "ads."

I am convinced that this is not the point of view taken by most, if not all, the advertisers, and that on the contrary they consider it a good business proposition.

On the other hand, it is evident that their "ads" can be made still more desirable and valuable by the attention of the members

of the Association to this matter, and I believe it is an obligation upon the members to give especial attention to the list of advertisements.

There is, of course, no obligation to pay higher prices, because the advertisements have been taken, but if the members will give a greater amount of attention to the advertisements, their value will be correspondingly increased.

I hope that during the coming year all subscribers to the JOURNAL will make it a point to familiarize themselves with the "ads." more carefully than ever before, so that our JOURNAL may become recognized to a still greater extent as the leading advertising medium for all water-works supplies.

I am sure you will cordially coöperate along this line.

PRESIDENT KILLAM. Anything further to be said for the good of the Association?

MR. ALLEN HAZEN. Your Committee on Meter Rates was discharged two years ago, but there have been some happenings since which may be of interest to members of the Association. The form of water rates that was adopted by the Association has been put into effect by the Hackensack Water Company, supplying several hundred thousand people in the state of New Jersey; and during the past year it has been put into effect by the Spring Valley Water Company in San Francisco with some 70 000 services and by the East Bay Water Company, supplying Oakland, Berkeley, and Alameda, also with some 70 000 services; and the rate established by the Railroad Commission was in the general form, although not the exact form, of the Association's rate. Mr. Sherman tells me, also, that the rates in that form have been adopted in Middletown, Conn. So rates in the Association's form have been adopted and are in use to-day by a population in excess of a million people. That is quite a progress report, I think, and I am glad to make it to the Association. [Applause.]

MR. CARLETON E. DAVIS. I think perhaps some members of the Association might be interested in this: At the time of the annual convention, when the subject of locating underground leaks was up, I mentioned a certain contrivance which one of the Philadelphia Water Bureau men devised. Since that time he has developed it rather extensively. So far as I know,

it is an enlargement of the stethoscope. The machine sells for about ten dollars, and thus far it has proven very successful. It is about the shape and size of the receiver of a telephone, with a little projection at the bottom to place on the ground or other listening point, and it has a tube with two branches, one of which can be inserted in each ear, and it has given some rather remarkable results not only in locating leaks but in locating the position of unknown underground pipes.

For instance, we were metering a certain building which had been erected some seventy-five years. It had no cellar, and there was one known service pipe. It was surrounded on three sides by streets, and when the service which was known and which was metered was shut off there was still water inside the building, so it was desirable to find the pipe. This listening device was placed on a spigot in the back yard, and then a man with a crowbar started to tap on the pavement above the mains surrounding the property on three sides. When he got to a certain point the sound was carried some one hundred feet to the listening point. It grew louder and louder, and then it died away, and at the point of the greatest sound they dug down and there was the missing service pipe. It appears to be rather an ingenious appliance, and one of the very nice things about it is that it is exceedingly cheap. It is portable, it can be put in your pocket, and apparently it can stand rough usage and is giving results.

MR. J. M. DIVEN. Is the device on the market?

MR. DAVIS. I think it is practically on the market. We have bought some ten or a dozen of them which have been made by hand; but there are dies now, so that they can be made in quantity.

MR. DIVEN. Is it advertised in the JOURNAL? [*Laughter.*]

MR. DAVIS. No. I am not financially interested, of course, but I should like to see the man make a legitimate profit. Now if he does advertise in the JOURNAL, how many will you buy? [*Laughter.*]

PRESIDENT KILLAM. We are always glad to hear from members from a distance. Mr. Hazen has spoken to us, and I see another man here from New York, Past President Smith. We would be very glad to hear from him. [*Applause.*]

MR. J. WALDO SMITH. I do not know that I have anything of interest to state to the meeting at this time. New York has had some difficulties in the last year. You all remember the conditions that were existing a year ago, when there was such an enormous consumption of water during the cold weather, and we felt then that it was most fortunate that the Catskill water had been delivered to New York a year in advance of that time. On the other hand, I think it was perhaps unfortunate that the people didn't have a little trouble, in order to bring them to a realization that the water was really needed, because even at the present time I think there are papers which defend the opinion that New York had water enough without the Catskill. But considering the fact that for a period of a year and nine months we have been using 425 million gallons a day of Catskill water, so that the Ashokan reservoir was depleted over 69 billion gallons, and the Kensico reservoir, which was always meant to be kept full except in times of emergency, was nearly half depleted, or about 12 billion gallons, the water-works people at least realize what a dreadful condition would have existed had Catskill water not been available. I don't think even the very serious condition which really existed at Jersey City, where they wouldn't even furnish water for the Erie Railroad, was any worse than it would have been in New York.

This condition of the Kensico reservoir was brought about by a very general increase of pressure all over the city, extending on the west side as far south as the Battery. In order to save as much pumping as possible, Catskill water has been used in excessive amounts to keep the pressure. But whereas the aqueduct will now deliver from the Kensico reservoir about 380 million gallons a day, the draft for a long period has been 425 or 450 million gallons a day, and in one period of the year it was over 500 million gallons a day, so they have been drawing the surplus out of the Kensico reservoir. Of course that cannot go on forever, and now by curtailing the waste and by pumping we hope to reduce the drawing from the Catskill so that the Ashokan reservoir in the course of a few years may fill up.

We all know from experience in our various water works how difficult a matter it is to educate the public — and public officials,

perhaps, more than the general public — to believe that some addition to the water supply is necessary; and still more difficult to induce them to grant to any administrative body sufficient authority so that a new supply can be developed with economy and with expedition. The Board of Water Supply is most fortunate that it has never found itself in the condition of the Public Service Commission who on the last day of the year were obliged to lay off from their working forces in the engineering department about 380 men at only an hour's notice, for the sole reason that through recent legislation they were tied to the Board of Estimates hand and foot. Not a salary could be increased, not a new position created, without an appeal to the governing body of the city, and the approval of the board of aldermen, and whereas this might and does work to some degree with a regular city department, whose business is somewhat uniform, it is an utter impossibility and will lead only to delay and expense with a commission such as the Public Service Commission building the new subway, or the Board of Water Supply which built the Catskill works.

MR. F. H. HAYES. Mr. President, I am an associate member, and I have to ask the freedom of the floor.

PRESIDENT KILLAM. It is granted, Mr. Hayes.

MR. HAYES. What I have to say has particularly to do with the associate members, and it relates to the subject of a certified check or a bidding bond. I endeavored to bring the matter before the Association two years ago, and it was placed on file, and I guess it has been on file ever since. The condition is this: We are asked to make prices for such material as we may be called on to furnish, and we have to put up either a bidding bond or a certified check. If we have several bids out, it ties up a considerable amount of money that is of no good to anybody. It loses interest the minute it leaves the bank, and it takes the chance of the bank not honoring the check if for any reason the bank should become insolvent. A bidding bond, which accomplishes the same object, comes from a responsible company and it is accepted.

Now, the question I want to get before this Association, and have tried to in the past, is for you to consider whether it is advisable to do, as the United States Government does, accept a

bidding bond, rather than to make us tie up money which becomes useless both to you and to us for a certain length of time. Sometimes it goes on for three months, and I have known of its going on for eight months. That is the reason I take this opportunity to bring the matter before the Association to see if we cannot have some action taken. I have talked to the associate members, and while they have agreed with me, they won't get up and talk about it; and if there is any way in which we can get it before one of our regular meetings as a subject for discussion I hope it will be done.

Mr. Carleton E. Davis. It seems to me this opens a very fruitful topic for discussion, and I think it is one which should be considered at some time in the near future. I think we might very well ask the Executive Committee to make it a topic for discussion, and I will make a motion to that effect.

It was voted to refer the matter to the Executive Committee, in order that it might be made a subject for discussion at a future meeting.

President Killam. I notice that another of our well-known members has come in, whom we are always glad to hear, and perhaps he will say a word to us, — Mr. Metcalf, ex-president of the Association.

Mr. Leonard Metcalf. *Mr. President and Gentlemen,* — I am rather taken back. I don't know quite to what subject you want me to address myself. The time of the Association is valuable, and I have not been here long enough to know what you have been considering to-day.

President Killam. We are interested in reconstruction work and would like it if you could give us something along that line.

Mr. Metcalf. I have been very much interested in the labor question, and its influence upon construction work at the present time; and I wonder somewhat what may be the opinion of the members of the Association present here to-day. It is very clear that at the present time considerable numbers of men, and women too, are being set adrift by the shutting down of the munition factories, and also by the gradual curtailment of work in certain lines of our staple industries, in a way which is likely to prove troublesome. I was in Schenectady, a week or ten days ago, and

found that the General Electric Company had shut off night work and overtime work, which had resulted in throwing, I don't remember the exact number, but thousands of employees out of their positions. I was told at the same time that various other works, like the American Locomotive Works, had shut down on their night work and were also curtailing in the output of their plant and cutting down the forces at work on day work. We are beginning to see it in this part of the country in growing measure, and we are face to face with the problem of furnishing permanent positions for the men returning from the front.

In this connection I might tell you a story about something that occurred in our office the other day, which amused me a good deal, and which bears a little on this question. My partner's son graduated a little more than a year ago from the Institute, and when the call was made for designers for service in the navy he took a special course given by Professor Peabody at the Institute, in naval architecture. Subsequently he went to New York and worked in the navy yard there, and then was ordered south to the Portsmouth, Va., yard, where he had charge of construction work. At the termination of the war he was face to face with a decision as to what he should do in the future. He came to New York and Boston and interviewed various men on his own initiative, and then at our suggestion, — and I think partly because his uncle was a representative of Kidder-Peabody,— he thought he would try banking, and we ourselves had the feeling that that would be a good field. So I gave him a letter to one of the partners of Estabrook and Company whom he went to interview. The gentleman very courteously gave him his time, told him about the conditions, and finally said that he felt very strongly it would be wiser for him not to go into the banking business, but to stay in the engineering business if he had been trained in that field, because, he said, in the first place, a great deal of the banking work had become highly commercialized, it was simply a commercial business, selling securities; and, in the second place, he said many of their men had gone to the front in response to the first call and others had been drawn in to take their places, and now these men were returning and would have to be placed, and they all felt that they ought to be placed.

Now, when you think of it, the humor of the situation lies in the fact that we as engineers were certain that the banking business was a desirable thing for a young man to go into, and a successful banker was quite certain that the engineering business was the thing. Everybody seemed to agree that the shipping industry, for which the young man had been specially trained or towards which his work would point, was likely to meet very, very serious difficulties under the Seamen's Act and the other limitations and demands of labor with which this Government is of course face to face. The shipbuilding industry is bound to let many men go in the near future, it seems to me, — it already has done so in certain yards, — and these men have got to get back to the normal industries.

The wage scale has not yet materially reflected the increase in the mobility of labor, or the increase in the supply of labor. Mill men say that they have already found that the question of getting labor is not so serious as it was, and that the general attitude of labor is changing with the increasing supply of labor, and they say that they believe that this will result in better conditions, lead to greater efficiency and a little better attitude, from their point of view, of labor generally. I cannot help feeling that we shall see a decline in the scale of wage, but there doesn't seem to be very much likelihood of decrease, particularly in the salaried positions, of permanent employees in water works, certainly not until there is a marked decline in the items which go to make up the cost of living, and those cannot well fall until after next summer, it seems to me, when the crops have been harvested, because of the very serious needs abroad; so that the readjustment in the intervening time of six or nine months promises to be a difficult one.

In this connection I was very much interested in the suggestion which a friend of mine made. He is an architect, and was interested in some work under the Housing Bureau. He had been revolving in his mind what could be done to make the conditions easier for labor, and this was his suggestion: Would it be possible in the building industry to make contracts through the labor organizations, on a basis which would presumably reflect fair current rates and would give organized labor the op-

portunity to get its wage? Then if it wished to work overtime or speed up the work, it would be perfectly possible for labor to increase its output by twenty-five or thirty per cent., and by working overtime to get a direct return within the time limit fixed for doing the work. In that way it would make it possible for labor to prolong the period of high return which it has been enjoying from overtime work, and at the same time benefit the person for whom the work was done, in that there would be greater certainty in the completion of the work, and that the very trying condition of having strikes towards the end and delays making it impossible to get into the building, would be avoided. I don't know that the scheme has been tried. Of course it is analogous to what used to be done years ago, when a man entered into a contract with a boss carpenter who got a lot of employees about him and did the work. But, of course, it is obviously open to the difficulty that, in doing that, organized labor would be taking a certain risk which it may feel it is not necessary for it to take. However, it is very clear from what has been going on and the statements of opinion that we have heard, that a great many men are thinking along the lines of what can be done to bridge over a very difficult situation. I think in a business way many of us are going to feel it much more in the coming six months than we ever have before, on account of the uncertainty which lies before us, and the fact that communities are not yet ready to go forward with confidence in ordering supplies and materials and doing work, because they expect that there will be lower rates of wages later. [*Applause.*]

Adjourned.

FEBRUARY MEETING.

HOTEL BRUNSWICK, BOSTON,
February 12, 1919.

President Samuel E. Killam in the chair.

The following-named members and guests were present:

HONORARY MEMBERS.

E. C. Brooks. R. C. P. Coggeshall. George A. Stacy.
Robert J. Thomas.—4.

MEMBERS.

D. L. Agnew.
S. A. Agnew.
J. M. Anderson.
Lewis M. Bancroft.
Jesse F. Barrett.
Wm. T. Barnes.
H. K. Barrows.
Geo. W. Batchelder.
Henry F. Beal.
Arthur E. Blackmer.
J. W. Blackmer.
C. M. Blair.
Bertram Brewer.
John C. Chase.
F. L. Cole.
John H. Cook.
Fred A. Darling.
J. M. Diven.
Lewis R. Dunn.
Harrison P. Eddy.
E. D. Eldredge.
Frank Emerson.
Almon L. Fales.
Geo. H. Finneran.
Albert D. Flinn.
H. F. Forbes.
F. L. Fuller.
Patrick Gear.
H. G. Gidley.
Frank J. Gifford.
H. J. Goodale.
X. H. Goodnough.
J. W. Graham.
H. A. Hanscom.
L. M. Hastings.
T. G. Hazard, Jr.
D. A. Heffernan.
Charles R. Hildred.
A. B. Hill.
W. F. Howland.
Jos. A. Hoy.
Lt.-Col. G. A. Johnson.
Willard Kent.
S. E. Killam.
George A. King.
P. J. Lucey.
S. H. MacKenzie.
H. V. Macksey.
A. E. Martin.
J. H. Mendell.
Leonard Metcalf.
M. L. Miller.
H. S. Noyes.
Thos. A. Peirce.
Henry E. Perry.
Albert E. Pickup.
Albert L. Sawyer.
Walter P. Schwabe.
Charles W. Sherman.
Geo. H. Snell.
Henry A. Symonds.
E. J. Titcomb.
Lewis D. Thorpe.
Fred'k I. Winslow.—64.

GUESTS.

MASSACHUSETTS.

Plymouth, Fred D. Bartlett.
Somerville, Frank E. Merritt.

ARKANSAS.

Camp Pike, Mayo Hunter.
Harry J. Robinson, U. S. Navy. — 4.

ASSOCIATES.

Ashton Valve Co., by Harry H. Ashton.
Builders Iron Foundry, by A. B. Coulters and E. C. Steer.
Central Foundry Co., by P. W. Conrow.
Chapman Valve Mfg. Co., by J. T. Mulgrew.

Eddy Valve Co., by H. R. Prescott.
Hayes Pump and Machinery Co., by F. W. Hayes.
Hersey Mfg. Co., by J. Herman Smith.
The Leadite Co., by Geo. McKay, Jr.
Ludlow Valve Mfg. Co., by Arthur R. Taylor.
Metropolitan Water Works, by A. O. Doane.
H. Mueller Mfg. Co., by Chas. G. Haas.
National Meter Co., by G. Lufkin and H. L. Weston.
Neptune Meter Co., by N. H. McGarry, Jr.
Pittsburgh Meter Co., by G. C. Northrop.
Rensselaer Valve Co., by Chas. L. Brown and Irving A Rowe.
George H. Sampson Co., by W. T. Page.
A. P. Smith Mfg. Co., by F. L. Northrop.
Thomson Meter Co., by E. D. Higley and E. M. Shedd.
Union Water Meter Co., by H. W. Jacobs and Donald K. Otis.
United Brass Co., by Geo. A. Caldwell.
United States Cast-Iron Pipe and Fdry. Co., by W. P. Mosteller.
United States Rubber Co., by J. H. Learned.
Wallace and Tiernan Co., by H. K. Davies.
Warren Fdry. and Mach. Co., by H. K. Kinsey.
Water Works Equipment Co., by W. H. Van Winkle.
R. D. Wood & Co., by H. M. Simons.
Worthington Pump and Machine Corp., by Samuel Harrison, Willis F. Bird and E. P. Howard. — 34.

The Secretary announced that applications for membership had been received from A. R. G. Booth, Lowell, Mass., assistant chemist, Mass. State Department of Health; Thomas J. Carmody, Holyoke, Mass., water commissioner; George M. Graffam, Portland, Me., auditor for Portland Water District and Bangor Water Works; W. W. Nye, Fairfield, Me., real estate; A. B. Thompson, Waterville, Me., assistant superintendent, Kennebec Water District, — all properly endorsed and recommended by the Executive Committee.

On motion of Mr. Edwin C. Brooks, the Secretary was directed to cast one ballot in favor of the applicants, and, he having done so, they were declared duly elected members of the Association.

The Dexter Brackett Memorial Medal.

The President. The first matter on the program this afternoon is the presentation of the Dexter Brackett Memorial Medal to Albert L. Sawyer. Mr. A. D. Flinn will make the presentation.

MR. A. D. FLINN. *Mr. President and Members of the New England Water Works Association,* — It is quite unexpected that this privilege should be mine to-day, but in coming into the meeting I was informed that the other members of the committee on the award were not here, the distant member, as sometimes happens, being present when the man who lives near by is not.

It is a genuine pleasure to be able to present this medal on this the second occasion of its award, not only because of the worthiness of the recipient, but because of my own very close intimacy with Dexter Brackett. When I first came to Boston as a youngster, a few years ago, it was with Dexter Brackett that I was very early associated, and it was with him that a very pleasant intimacy and friendship grew up, which lasted throughout the remainder of his life; and I see all around me men with whom I became acquainted through Mr. Brackett, — Mr. Coggeshall, for example, who sits here just before me. And so I was introduced to the New England Water Works Association by Mr. Brackett.

When Mr. Brackett finished his work among us, not so very long ago, it seemed most proper and pleasant that some token, some constant reminder of his work for this Association should be established. And you will remember that Mr. Brackett had a very high ideal as to the work of the New England Water Works Association, that it was to be helpful to various kinds of men, men engaged in various activities that were associated with it. And so it is a peculiar privilege in awarding the medal at this time to know that the Association is giving it to a man who has contributed to our work in a branch which sometimes, perhaps, we have failed to appreciate,— that branch of management and direction which deals with the accounts. It is therefore a peculiar pleasure to give to Mr. Sawyer, as the author of the paper on "Some Advantages of a Classified Cash Book," this medal. The paper, as you will remember, was presented at the Portland meeting in 1917, but, although it has taken so long to determine who was the worthy man, and to get the medal into your hands, Mr. Sawyer, please do not consider there was any lack of appreciation on our part of the value of your contribution to our Proceedings.

I now present to you this medal. [*Applause.*]

MR. ALBERT L. SAWYER. I thank you very much for your

kind words, and I receive the medal with a great deal of pleasure. I have always thought that I should very much like a medal, but up to this time I have never been fortunate enough to secure one. At the time of the Civil War I was too young to go, and I was too old to go to the last one, consequently I have had to be content with tags and buttons. I don't know how it has been in your towns, but I will say that in my town I have been able to accumulate a large and varied assortment of them. [*Laughter.*] I should think that about everybody who was represented at the building of the Tower of Babel and on the day of Pentecost has had a drive in my town, to say nothing of such purely local affairs as the Blossoms of Zion, the Boy Scouts, and Rescue Mission.

I was greatly surprised when I received a letter from Secretary Kent announcing that I was to receive this medal. Of course personally I had no doubt that my paper was a most worthy one [*laughter*], but that the Committee on Award should say so, and the Executive Committee back them up, and thus make it unanimous, was really more than I had any reason to expect. One thing, leaving out the personal element, that has appealed to me is the fact that while the first medal was awarded to an engineer, the second has been awarded to a representative of the office department of water works, showing that this memorial trust is to be administered in the most catholic manner. And I have an idea, now that one water registrar has received this medal, every other water registrar will decide that he wants one, and I wouldn't be surprised if hereafter there were so many papers from registrars and treasurers that the engineers and superientendents will have to sit up and take notice, or we shall be carrying off all the honors. [*Laughter and applause.*] Knowing as I do the high reputation attained in engineering and water works administration by members of this association, and also the high class of papers presented, I certainly consider it a great honor to receive this medal, and while I have a feeling that I am not worthy to receive it, I gratefully accept the decision of the committee.

I shall hereafter enter the date February 12 in my personal calendar as a red-letter day, celebrating not only the birthday of Abraham Lincoln, but also the day on which I received the Dexter Brackett Memorial Medal. [*Applause.*]

An Address by Lieut.-Col. George A. Johnson.

The President. We have with us to-day an honored member of this Association who told me a little while ago that he belonged to about all the societies there were a-going, and that he placed the New England Water Works Association among the first. [*Applause.*] He also laughingly suggested that he was thinking of making an application to the Colonial Dames for admission to their society, and I told him I hadn't any doubt but that he would at once be accepted on his uniform and his good looks. [*Laughter.*] It now gives me great pleasure to call on Colonel Johnson. [*Applause.*]

Lieut.-Col. George A. Johnson. *Mr. President and Members of the New England Water Works Association,* — This is quite unexpected. [*Laughter.*] When I was accosted by your worthy President, — our worthy President, I should say, — he asked me if I would say a few words to you to-day about the work of the Construction Division of the Army. I think you will judge from the state of my voice that I have been saying quite a few already.

Lots of us were either too fat to fight or too old — as the recipient of the medal suggested — to do our bit at the front, but it was our good fortune to be placed at least in the home forces to carry on the work here at home. Active warfare is for youth; it is the supreme moment for them. But without the second line and the third line and still other lines back of them until they finally reach back to us here, youth could not go forward and experience that supreme moment.

The Construction Division of the Army is an organization of which little has been said. Everybody in it, from the chief down, has been too busy to make public speeches or to write public stories. Shortly after the war broke out in April, 1917, there came the duty of providing quarters for the new army, not only places for them to sleep in, but complete facilities. Then in charge of such construction work was the Construction and Repair Division of the Quartermaster-General's office. It was hoped at the time that that division would expand so as to be able to take this tremendous load, but it did not advance fast

enough. With the aid of civilian engineers and civilian advisers, — among the most worthy were those coming from this territory, — there was formed the Construction Division of the Army reporting direct to the Chief of Staff, the only division in the War Department reporting direct to the Chief of Staff.

We wish to make it very plain that we are not connected directly with the Quartermaster-General's office. We wish to have it understood distinctly among you gentlemen that the Construction Division of the Army is the civilian engineer division of the War Department. That seems to have been somewhat misunderstood. It also seems to be the general conception that we are a part of the Engineer Corps of the army, which we are not. We have a distinct work to perform, a work which no one has ever done but the civilian engineers, whether in uniform or not.

When America entered the war one of her problems was the housing of the new army. For the expeditious creation of complete cities, each housing an average of forty thousand men, the engineer, the architect, the city planner, the constructor, and the labor agent were called into the service as the Construction Division of the army. Instead of attempting to set up a number of organizations, it went to the civil life from which it sprang, and called upon the existing contracting organizations, engineers, and producers of materials, to aid in the accomplishment of its task.

The magnitude of the undertaking cannot be over-emphasized. In a little over three months the Cantonment Division was expected to have suitable quarters ready for the training of over 1 000 000 men.

The work of the Construction Division, in magnitude, speed of accomplishment, number of workmen employed, and materials involved, dwarfs any other construction or engineering project the world has ever known. The Panama Canal required ten years to construct, and cost approximately $375 000 000, whereas the work of the Construction Division for one year and a half exceeded three times this amount. While the work was being done, there was a shortage of labor and materials and congestion of transportation facilities unequaled in the world's history.

At one time 200 000 men were employed in the field alone.

The work included 535 operations at 442 different and widely separated locations.

The housing accommodations comprise about 40 large camps and several hundred minor projects, providing accommodations for more than 2 259 000 men. In the case of camps, a complete city was built, including roads, walks, electric lights, water supply, sewers, sleeping quarters, mess halls, lavatories, theaters, post-offices, store buildings, telephone and telegraph offices, power houses, laundries, storage buildings, hospitals, stables, garages, etc.

At army bases, interior posts and expeditionary depots, warehouses, terminals, piers, wharves, and docks have been constructed on an hitherto unequaled scale. The areas total 27 502 300 sq. ft. of warehouses and pier sheds and 2 176 000 sq. ft. of open sheds, giving a grand total of substantially 30 000 000 sq. ft., or 690 acres, of storage space. This equals a building 70 ft. wide and 80 miles long, or about equal in length to the distance from New York to Philadelphia. Most of the warehouses are of reinforced concrete. These figures do not include miscellaneous warehouses, magazines, or those at camps, or used exclusively by the Ordnance Department. Adjacent to the terminal piers and docks there are 39 000 lin. ft. of wharves, equivalent to 7.4 miles, for loading ships. This wharfage provides channels with a depth of 35 ft. at low tide, and is sufficient to berth 65 ships at one time on the basis of 600 ft. in length of wharf per ship. There have been built 1 644 miles of railroads exclusive of local trestles, etc., and 1 061 miles of roads of which a large percentage are concrete.

The Hospital Section has built or reconstructed buildings to accommodate 121 000 patients' beds, and in addition has provided quarters for about 12 000 nurses, 24 000 enlisted personnel, and 4 000 doctors.

For the Ordnance Department, alone, there have been built more than 7 933 000 sq. ft., or 181 acres, of industrial and storage buildings, about 7 000 lin. ft. of docks, and about 3 250 000 sq. ft. of magazines. The work for the Ordnance Department and the Chemical Warfare Service has aggregated at cost of about $150 000 000, of which the following is a brief description:

Six artillery proving grounds, of which the largest, at Aberdeen, Md., contains about 38 000 acres and has cost about $15 000 000.

Seven ammunition storage depots, of which the largest one, at Raritan, N. J., contains over 150 fireproof magazines, has a storage capacity sufficient for nearly $400 000 worth of explosives, and cost about $12 000 000. Most of these depots are provided with extensive dock facilities and from twenty to thirty miles of railroad sidetracks.

Various fireproof building construction of steel, brick, reinforced concrete, and hollow tile, together with the installation of miscellaneous machinery, etc., at nine of the permanent government arsenals, which are scattered from New England and the Atlantic Coast to California and Texas. At Watervliet it included a steel and concrete machine shop about 250 ft. by 600 ft., and other buildings of like character, which added about four thousand to the manufacturing force at that point.

Nine plants for assembling ammunition, etc. Several of these installations cover three or four square miles, contain three to five hundred separate buildings in the one plant and thirty or forty miles of side tracks, besides power station, machinery, and equipment of all kinds.

Twenty chemical manufacturing plants, with their buildings, facilities and equipment. These plants cost from $1 000 000 to $13 000 000 each, and in most cases included housing facilities for the operating forces, as the plants were necessarily isolated.

The Edgewood Arsenal, at Edgewood, Md., includes an extensive plant for producing chlorine and other gases, an extensive gas shell filling plant, fireproof barracks, two hospitals, 600-ft. dam and reservoirs, and a 20 000 kw. power station, and cost about $25 000 000.

The work of the Construction Division, summed up briefly, has covered such diversified projects as camps, cantonments, wharves, docks, forts, arsenals, great port terminals, reserve storage warehouses, hospitals, of all sizes and descriptions, aviation fields, proving grounds, embarkation camps, engineer camps, gunnery schools, housing, lighters, power plants, factories, additions to manufacturing plants, munitions plants, and special new plants, — for the production of nitrates, phosphorous, T.N.T. and other acids, gas, and explosives.

On top of the construction work there comes still another factor,

and that is the operation of these institutions. In the Construction Division there is the Maintenance and Repair Division. I have always thought that the nomenclature was somewhat unfortunate. We in civil engineering life are more fond of operation and maintenance. This division to-day has complete charge of the operation and maintenance of establishments, consisting of the major camps and cantonments, some 50 odd hospitals, 25 terminals and storage depots, together with the 66 border stations and the regular army posts. We have a force of 501 commissioned officers and 16 559 enlisted men. Those are spread over the establishments. All of the work of those establishments is directed from the Washington office. Much of the time the Washington office is directed from the field, for we don't let the tail wag the dog. We in Washington realize that our duty is to endeavor to work out the problems as they come to us from our men in the field, to judge them, to act dispassionately upon their reports to us, and to see that the men in the field are supplied with money and with men and with facilities to do their work. We know that the man in the field has a much harder job than we have. He is dependent to a large extent on us, but more largely on his own resourcefulness; and the way he has come through in this job is marvelous.

In the field there is a utilities officer. Under him are chiefs of sections. Each utilities officer functions just the same as a city manager functions in civil life. We are the head office of the city managers. The duty of the utility officer in each one of these establishments is to maintain the roads and keep them in good condition; and when we realize the intensive use to which they have been put in this last year and a half you can imagine what a gigantic task it has been. The buildings, put up without painting, have fallen into bad repair. Those have to be kept up. Windows have to be kept tight; the roofs have to be kept tight; the electric-lighting systems, put down hurriedly and without mature consideration, have to be revamped; and they have to function with high efficiency, or else the man gets " bawled out " by the Washington office, where we have expert electrical engineers to check up the work in the field.

In each camp there is, of course, a water department. In some

places the water is purchased; in others it is produced independently. The water has to be filtered in some cases, and experts in that line are on the job. The sewerage systems, laid out hurriedly, as they had to be, have in all cases proved adequate, and that is remarkable when it is considered how swiftly they were put down. The disposal of the sewage has to be taken care of the same as in civil life, in order that there may be no nuisance created through the discharge of the effluent into streams. Heating plants have to be operated with high efficiency, in order that the men may be kept warm and comfortable, especially in the hospitals. Refrigeration plants have to be run in order to keep perishable foods and to manufacture ice for issue. The whole problem is one of tremendous city management, because even though in sum totals they may only run into a couple of million men, the communities themselves are so widely scattered in so many localities, with so many different factors governing.

Then as to costs. We have made a complete and careful analysis of the costs of operation of all of these utilities, and we are prepared to state and prove by actual figures that the electric-lighting systems, the roads, the buildings, the heating plants, the sewerage systems, all of those things that make up a modern city, have been operated and maintained at a cost not higher and even in some cases lower than those in the best managed commercial projects or best managed state or municipal institutions. That is a strong statement, but we can substantiate it by figures and facts. And we take pride in it in giving an account of our stewardship. It has been a big job, and we are all proud of it.

There were a great many men — I think you might say 101 per cent. of us, — who wanted to go abroad, but our duty was here; we could do better work here than we could there. There is a glamour, of course, to be spread over foreign service. There is also a glamour to be spread over self-sacrifice. We have in our force a great many young men who have been thrust back because of some physical disability, and there are others who were judged to be too valuable to be sent. And when the final summing up comes of " who is who " in the war there must be a tremendous amount of credit given to those who have so ably served in the Construction Division of the Army, who are entitled to a high

place in history and who, I think, will never be forgotten when the story is fully told. [*Loud applause.*]

THE PRESIDENT. Mr. Fales, the chairman of the Sanitary Section of the Boston Society of Civil Engineers, has an announcement to make.

MR. ALMON L. FALES. At a meeting of the Sanitary Section of the Boston Society of Civil Engineers we are going to have the pleasure of hearing Colonel Johnson tell us of the operation and maintenance of the utilities at the army camps and cantonments. I am sure from what you have heard him say this afternoon that you will all be interested to hear in detail of his work. In the name of the Sanitary Section I extend to the members of the New England Water Works Association a cordial invitation to come to that meeting, which will be held at the Engineers' Club at 7.45 P.M., on Wednesady, March 5. Preceding this meeting we are to give a dinner to Colonel Johnson, and we shall also be very glad to have you join with us in thus honoring him. The dinner will be at 6.30, and I will ask any of you who wish to join with us to send a card to that effect to our clerk, Mr. Henry A. Varney, 715 Tremont Temple, Boston.

THE PRESIDENT. In behalf of the Association I thank you for the invitation, and I will see that our members are notified in due time.

I have been requested to call attention to House Bill No. 760, now before the legislature, on which there is to be a hearing next Monday before the Joint Judiciary Committee. This is a bill to make water bills a lien on property. It has been up several times before, but I do not think it has ever got out of the committee.

Mr. Metcalf has written me a letter, but as I see he is present I will ask him to state to you personally what he has stated in the letter to me.

MR. LEONARD METCALF. *Mr. President and Gentlemen,* — I was anxious to find out for some water-works men whether any of you had information or experience upon agreements between water works and municipalities, looking to the taking over of the works by the municipality on a basis under which it was possible for the municipality to make payments of given sums from time to time, and under which any surplus earnings above a certain amount,

specified in the agreement, were to be applied to the purchase of the works.

It has been suggested that some such method as this might be used, as means of settling questions which were vexed, between the water company and the municipality, particularly if there should be represented on the directorate of the water company the city authorities. One of my clients has been considering the making of such an agreement as that, based upon allowance of a certain rate of return upon the outstanding stock of the company, as well as the interest upon the bonds, — an agreement being arrived at with the city in regard to the relation between the outstanding securities and the fair value of the property.

It seemed to me that this subject was one which would interest water-works men, and that it had in it a germ of thought that might be useful to water works, and so I am anxious to find out whether any of our members have had any experience of this sort.

The plan is somewhat analogous to that which was developed in Chicago in settling the electric railway situation, and I think on the whole has worked out fairly well there. It is my impression that the city of Louisville, Kentucky, took over its water works on some such basis. The details I have not yet been able to find out about, though I expect to have information in the course of a few days. In the case of Burlington, Ia., I find that there was another example of an agreement under the terms of which the city has already acquired a very substantial interest in the works, which are still being operated by the water company; and the city is looking forward to finally acquiring the works under terms which are acceptable to the water company, and which the city officials consider distinctly advantageous to the city.

I should be very grateful, therefore, if any of you know of any such examples, if you will let me know, or let one of the members of the Executive Committee know, of them, so that they may be rounded up for presentation at a later date at one of our meetings.

THE PRESIDENT. Is there any one present who can give us any information on the subject now? It appears to me to be a very interesting matter.

MR. SAMUEL H. MACKENZIE. The town of Southington took the works from the Southington Water Company, and they acquired them under an agreement that they should pay the cost of the works plus six per cent. less the dividends. It is a little more complicated than it seems from that statement, perhaps, but that is the way the works were acquired.

THE PRESIDENT. It seems to me this is a very interesting subject, and I trust that Mr. Metcalf, after he gets the information together, will at some date present it in such form that it can go into our records for reference.

The President then called upon Mr. Robert E. Horton, hydraulic engineer, Albany, N. Y., who read a paper entitled, "Measurement of Rainfall." The subject was discussed by Mr. Desmond FitzGerald, Mr. R. C. P. Coggeshall, Mr. Charles W. Sherman, and Mr. X. H. Goodnough.

Mr. L. M. Hastings, city engineer, Cambridge, Mass., presented a paper entitled, "Some Practical Uses of Rainfall Records."

Adjourned.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association was held at headquarters, Tremont Temple, Boston, Mass., at 11 o'clock A.M., December 11, 1918.

Present: President Carleton E. Davis, Samuel E. Killam, Henry V. Macksey, Thomas McKenzie, Frank J. Gifford, Lewis M. Bancroft, and Willard Kent.

The following applications were received and recommended for membership, namely, John W. Moran, superintendent water works, Fall River, Mass.; Timothy W. Good, superintendent water works, Cambridge, Mass.; Willard A. Keene, manager Turtle Creek office, Pennsylvania Water Co., Turtle Creek, Pa.; Launcelot P. Marshall, chief engineer, Rangoon Municipality, Rangoon, Burma, India, and V. T. Givotovsky, post-graduate student, Mass. Inst. of Technology, Allston, Mass.

The death of James Burnie, vice-president of the Association in 1901, 1902, 1905, and 1915, was announced as occurring on the 27th of last month, and the preparing of an obituary notice was referred to the Editor.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Wednesday, January 8, 1919.

Present: President Carleton E. Davis and members Samuel E. Killam, Henry V. Macksey, Percy R. Saunders, Lewis M. Bancroft, and Willard Kent.

The application of Schumaker & Santry for associate membership was presented and unanimously recommended therefor. The report of the committee on Award of the Dexter Brackett Memorial Medal for the year 1917 was received, and it was unanimously

voted, that the award of the Dexter Brackett Memorial Medal for the year 1917 be, and hereby is, made to Mr. Albert L. Sawyer, water registrar of Haverhill, Mass., for his paper entitled, "Some Advantages of a Classified Cash Book."

Voted, that Messrs. William T. Barnes, William F. Sullivan, and George W. Batchelder be and hereby are constituted a committee to recommend the award of the Dexter Brackett Memorial Medal for the year 1918.

Adjourned.

Attest: WILLARD KENT, *Secretary*.

Meeting of the Executive Committee of the New England Water Works Association held at headquarters, Tremont Temple, Boston, Mass., February 12, 1919, at eleven o'clock A.M.

Present: President Samuel E. Killam and members Henry V. Macksey, Charles W. Sherman, James H. Mendell, Frank J. Gifford, Patrick Gear, Willard Kent, and Lewis M. Bancroft.

Voted, that the President be and hereby is authorized to appoint a committee with full power to make arrangements for the June meeting of the Association.

Voted, that Messrs. A. R. Hathaway and Patrick Gear be a committee to investigate and report with reference to the place of holding the next annual convention.

The question of printing the membership list for the current year is discussed and referred to the President for such action as he may deem best.

Voted, that the President be and hereby is authorized to make arrangements to allow the associate members to conduct a portion of some meeting of the Association after the dispatch of the routine business.

The Secretary presents certificate of renewal of the Treasurer's bond for two thousand dollars by the Massachusetts Bonding Company, which is by unanimous vote approved.

The following applications, properly endorsed, are received and the several applicants are by unanimous vote recommended for membership of the Association, viz., A. R. G. Booth, Lowell,

Mass., assistant chemist, Mass. State Department of Health; Thomas J. Carmody, Holyoke, Mass., water commissioner; George M. Graffam, Portland, Me., auditor for Portland Water District and Bangor Water Works; W. W. Nye, Fairfield, Me., real estate; A. B. Thompson, Waterville, Me., assistant superintendent Kennebec Water District.

Adjourned.

Attest: WILLARD KENT, *Secretary.*

ROLAND DWIGHT BARNES.

Word is just received of the death of Roland Dwight Barnes, which occurred at his home in Bristol, Conn., in August, 1918, after an illness of two years, although he was able to attend to business till within about two weeks of the end.

Mr. Barnes was born December 23, 1855, and received his education in the schools of Forestville and Bristol, Hartford High School and New Britain Normal School. After teaching school a short time he took up the practice of his profession, that of civil engineer, with the Bristol Water Company, building their first reservoir and continued as their engineer till 1887.

Mr. Barnes then became associated with the Pittsburg Water Works and Guarantee Company of Pittsburg, Pa., building water works in various parts of the country, and later transferred his office to Boston and was connected with development of water power on the Androscoggin River at Rumford Falls, Me. He then spent about fifteen years on construction and maintenance of sewers in Malden, Mass., from which he returned to Bristol and supervised house and factory building for the Bristol Brass Company, and was employed by the Wallace Barnes Company at the time of his death.

He is survived by his wife, daughter, and a brother.

Mr. Barnes was a member of the New England Water Works Association from 1899, and was associated with the Methodist Church and was a member of the board of trustees, also with the Independent Order of Odd Fellows and Knights of Pythias.

He was one of Bristol's best citizens, of high standing in his profession and upright and honorable in all his dealings.

The New England Water Works Association, in common with his town and state, has lost an honored member.

CHARLES HENRY BALDWIN.

The passing of Charles H. Baldwin, which occurred January 23, 1919, takes away one who had made a remarkable record in several fields of activity. Mr. Baldwin was born January 13, 1852; was " turn-on " and " turn-off " clerk of the Boston Water Department from 1874 to 1883. Then followed two years with

the Equitable Meter Co., which he left to become New England manager of the National Meter Co., a position he held with the greatest credit till July 1, 1913, when he was made president of the Franklin Savings Bank of Boston.

In this work he was eminently successful, and closed his career having gained and retained the highest esteem, respect, and confi-

dence of a legion of acquaintances. Mr. Baldwin was an active member of the New England Water Works Association from 1887 but had been an associate member previously.

For many years he was active and took a deep interest in its affairs.

He first appeared before the Association at the Worcester Convention of 1883, to discuss "The Causes and Prevention of the Waste of Water," and was present at nearly all gatherings and took an active part in the programs. At the joint convention of the American and New England associations, held at Young's Hotel in April, 1885, he did very effective committee work.

Mr. Baldwin's circle of interests included membership in Society of Colonial Wars, treasurer of Home for Aged Men, director of the Washingtonian House, member of Trinity Church and deeply interested in the affairs of the diocese.

He is survived by his wife.

Although his many business demands prevented active participation in water-works affairs during the last few years, the Association feels a distinct loss in the passing of one who had been a strong factor in making the New England Water Works Association the powerful organization it is to-day.

IN MEMORIAM

LETTICE RODERICK WASHBURN.

Born March 14, 1848. Died December 27, 1918.

Member New Bedford Water Board from June 23, 1904, to the date of his death. Joined this Association March 11, 1908.

BOOK REVIEWS.

"Conveyance and Distribution of Water for Water Supply." By Edward Wegmann, C. E.

(Reviewed by Fred O. Stevens.)

In the seven hundred pages of his "Conveyance and Distribution of Water for Water Supply," Mr. Wegmann has assembled a vast amount of water-works data from the leading textbooks, journals of engineering societies, technical magazines, and trade catalogues, of this and other countries.

Part I gives, in a concise manner, the deduction and application of such formulas as are necessary for the solution of the ordinary problems relating to the flow of water in pipes and channels, with tables of coefficients to be used with them. The data on loss of head due to curves and valves are much more comprehensive than that found in textbooks, and the coefficients given are the result of a large number of experiments.

Part II, treating of design and construction, takes up briefly but clearly the analysis of stresses in cast-iron, wood, and riveted-steel pipes, standpipes and trestle towers, together with enough of the mechanics of materials to enable the engineer-superintendent to solve intelligently such problems of design as are apt to occur in connection with his everyday work.

Methods of manufacture of the various kinds of pipe are fully described, as are also construction methods for a number of water-works structures; but the greater part of this section is taken up by descriptions of notable existing works in this country and abroad, some one hundred pages being given to descriptive matter on intakes and aqueducts, an amount of space which seems somewhat out of proportion to that allowed some other subjects, in a volume which is described on its title page as "a practical treatise for water-works engineers and superintendents."

The subject matter of Part III, on maintenance and operation should, prove of great interest and value to beginners in water-works management, to commissioners in small towns, and others who are called upon to administer the affairs of water systems without having had practical water-works experience.

The author describes the latest approved tools and appliances, fixtures and fittings, and water-measuring and recording devices, in great detail, with illustrations from trade catalogues of each article described. An example of the detailed description of tools and processes in this section is afforded by the following paragraph:

"After the lead has been poured, the surplus of lead is cut off with the lead-cutting chisel, and the joint is calked by means of the calking irons and a hammer weighing about $3\frac{1}{2}$ pounds. The thickness of the calking irons at the point varies from $\frac{1}{8}$ to $\frac{7}{8}$ in."

The paragraph is illustrated by cuts showing a full set of calking irons and hammers.

The chapter on water meters is in itself a treatise on all known appliances for the measurement of the flow of water through pipes. Not only every type, but practically every make of meter from the smallest disk to the largest Venturi, including the recording devices used with Pitot tubes, is described by means of text, cuts, and diagrams. It is to be regretted that the author could not have devoted a few pages to the subject of meter maintenance and repairs, which, although of great importance to superintendents, has hardly been touched upon in water-works literature.

The work as a whole is essentially a compilation, and as such will be of great value to the busy water-works manager who cannot possibly have access to the many sources of information of which the author has availed himself. Its greatest value to the engineer and to the superintendent of mature experience who desires to broaden his knowledge gained experimentally, lies in its abundance of references, which, without exaggeration, may be said to cover practically the entire field of literature on water distribution.

"WATER RIGHTS DETERMINATION." By Jay M. Whitham. — New York, John Wiley & Sons, 1918.

(*Reviewed by* CHARLES W. SHERMAN.)

This book is the outcome of Mr. Whitham's long experience in water-power rights cases, and represents the fruits of a very painstaking investigation in old books and pamphlets, reports of law cases, etc. In his preface, the author says:

"This book is intended to assist an owner of an indefinite water right in determining:

1. The meaning of his right as expressed in horse-powers; and
2. The number of cubic feet of water per second to which he is entitled."

The first part of the book contains data from many sources relating to the power required to operate a run of stones, a saw mill, a cotton mill, etc., as indicated by the various authorities which the author has been able to find.

The second part is devoted to a discussion of the quantities of water discharged through bulkhead gates and through various types of water wheels and turbines, more especially the older and now nearly obsolete types of wheel used in most of the early mills, to which such indefinite grants of water apply.

The book is destined to be extremely useful in every case of an indefinite water-power right.

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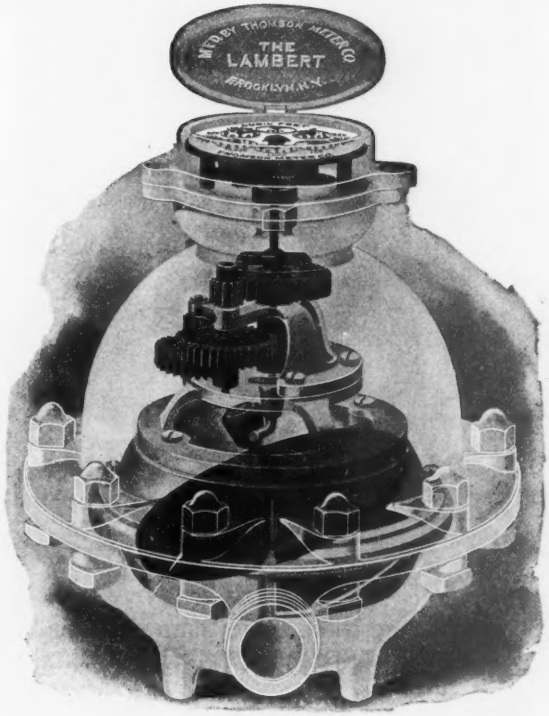

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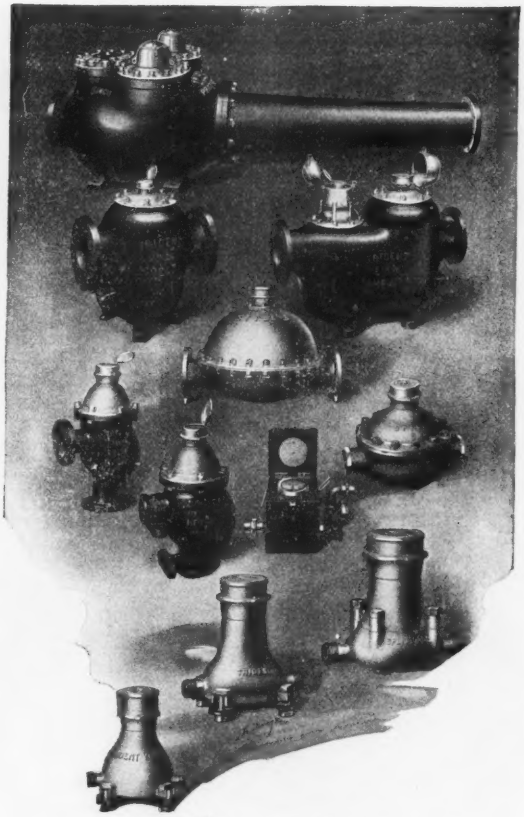

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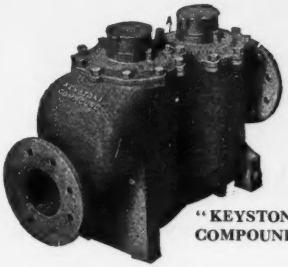

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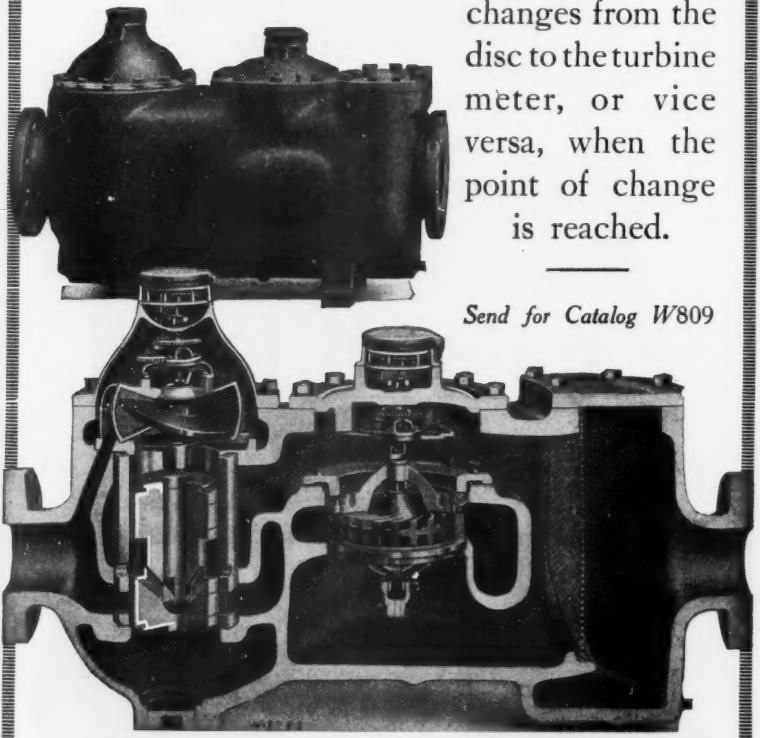

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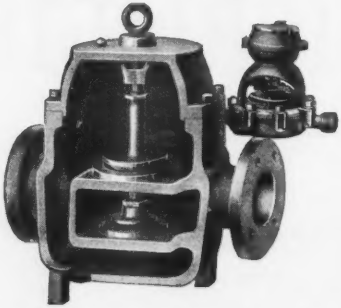

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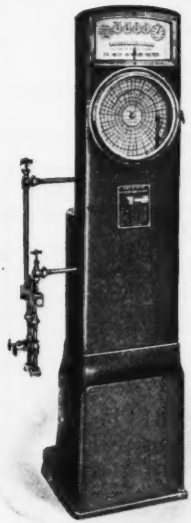

is quick to detect pump slippage. The new Type W instrument (illustrated in cut) will give you a continuous record as to the condition of your pump valves, and as to the actual efficiency of your pumps.

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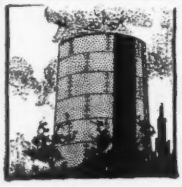

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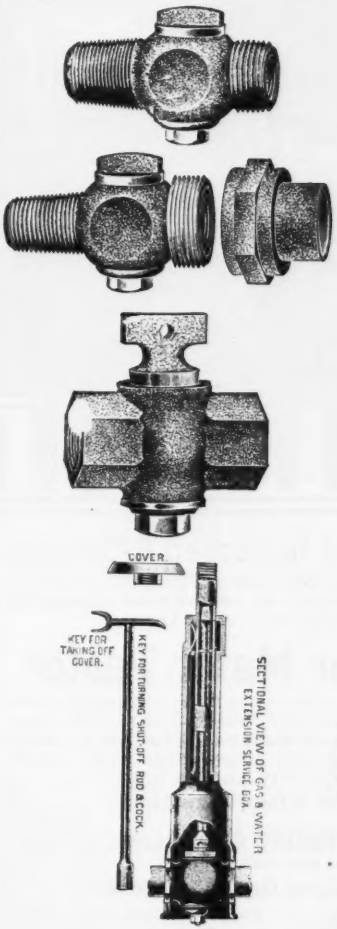

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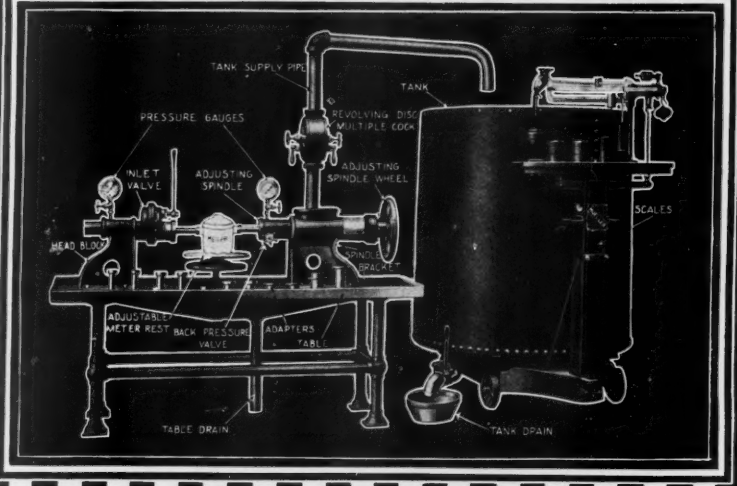

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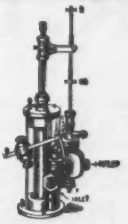

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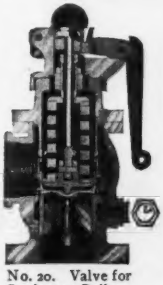

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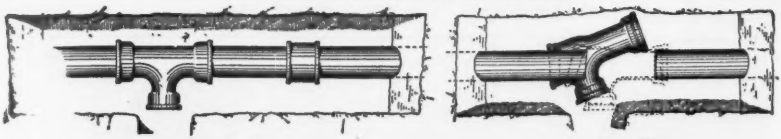

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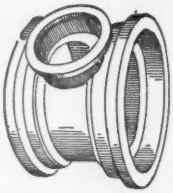

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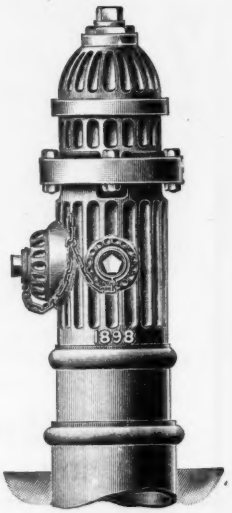

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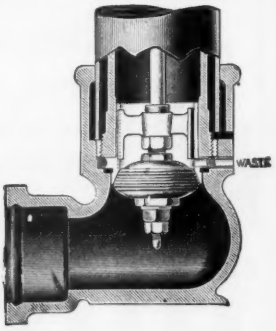

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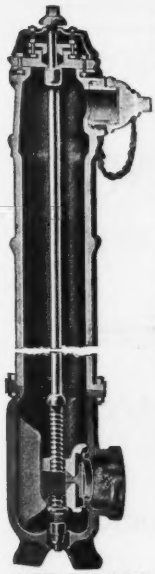

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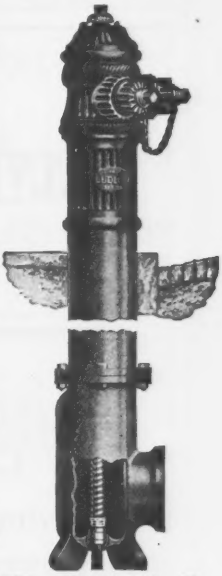
The drip is directly in the bottom of the hydrant and drains perfectly It is protected by its valve, which never leaves its socket and cannot be clogged.



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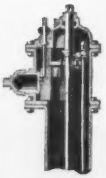
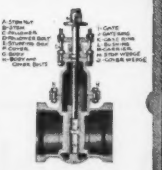
PATENT RUBBER FACED

EDDY FIRE HYDRANT

Section of Taper Seat-Valve.



Hydrant with Independent Nozzle Cut-off.



Section of Parallel Seat-Valve.

Section of Vertical Check-Valve.

Section of Vertical Foot-Valve.

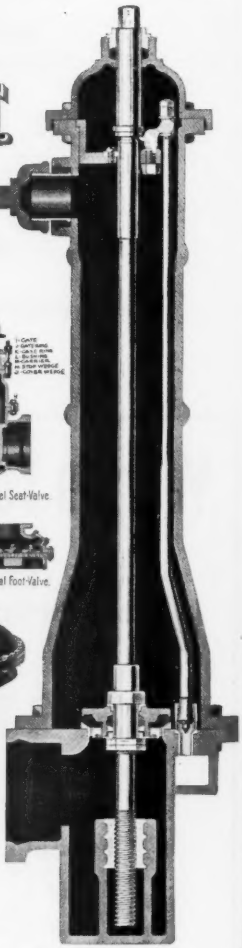
Horizontal Check-Valve.

Vertical Foot-Valve.

Hydrant with Water Crane Attachment.

Indicator Post.

Water Crane with Automatic Drip Valve



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Such is the latest story of Cast-Iron Pipe efficiency — and the efficiency of the good, old-fashioned bell-and-spigot joint.

There were 2,500 joints, and out of all that multitude only three showed slight signs of leakage when the line was tested.

At one point the line dipped through a lake, dropped 20 feet under water, then rose to the shore on the other side. The lake was narrow, — we'll show you a picture of that later, — so you can imagine the tremendous strain to which those joints were subjected. With that in mind just recall that only three joints out of 2,500 showed even a slight leak. Some 2,497 joints perfect, in spite of the rocky-road-to-Dublin conditions almost everywhere.

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For calking pipe joints under the most difficult conditions.

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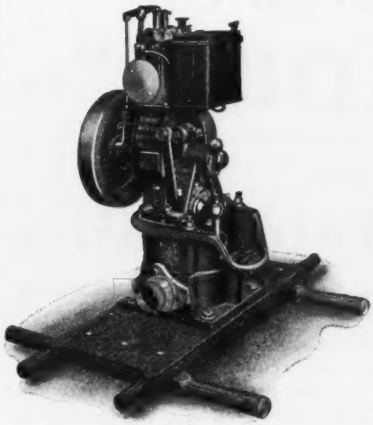

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This Engine is built for Diaphragm Pumps by the makers and inventors of the Pump.

Fifty years' experience is behind it — reliable as the original pump you have known for years.

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Trade "LEADITE" Mark

Registered U. S. Patent Office

FOR

Jointing Water Mains

1. **DURABILITY.** Leadite joints increase in strength with age.
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12. **USERS.** Progressive water works all over the country use Leadite.

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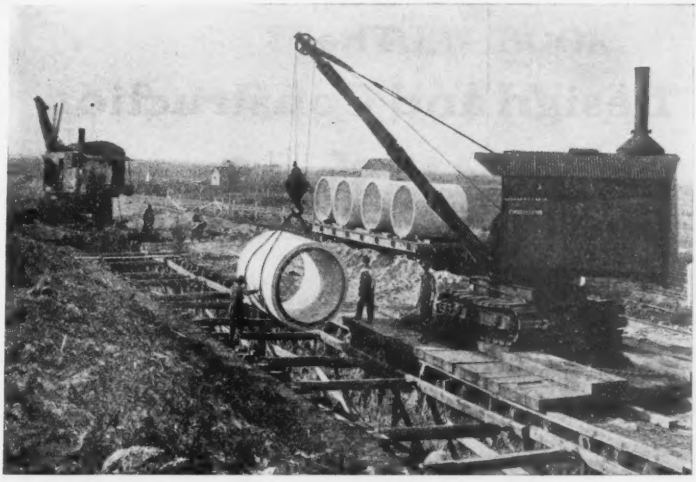

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Length, 10 miles.

Heads, 45 to 90 feet.

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New England Water Works Association,

ORGANIZED JUNE 12 1882.

APPLICATION FOR MEMBERSHIP.

I, the undersigned, residing at ..... *being desirous of admission into the New England Water Works Association, hereby make application for* ..... (*resident, non-resident or associate*) ..... *membership.*

I am ..... *years of age, and I have been engaged in the following named work:*

.....

.....

.....

I will conform to the requirements of membership if elected.

Signed, ...

Address, ...

Dated, ... *191*

Resident members are those residing in New England; all others are non-resident.
Entrance fee is $5.00 for resident and $3.00 for non-resident members.
Annual dues are $4.00 for both resident and non-resident members.

Patronize

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